The Neighbourhood
Planning and Design Guide

Creating Sustainable Human Settlements

Red Book

Part I

Setting the scene

Feedback and comments on this Guide would be welcome. It will assist the Department of Human Settlements in adapting and updating the document, ensuring that it remains useful and relevant. For feedback, or to request more information, please make use of the contact details below.

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The Neighbourhood Planning and Design Guide
Creating Sustainable Human Settlements

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Preamble

Introduction

The Neighbourhood Planning and Design Guide is a comprehensively updated and revised version of its predecessor, the *Guidelines for Human Settlement Planning and Design*, commonly known as the *Red Book*. The Red Book, published in 2000, was preceded by a series of guideline documents aimed at improving the quality of settlement planning and design.

Historical background

Recognising that the cost of engineering infrastructure and services contributes significantly to the overall cost of housing, the Council for Scientific and Industrial Research (CSIR) published the *Guidelines for the Provision of Engineering Services in Residential Townships (Blue Book)* in 1983. This was followed by the publication of *Towards Guidelines for Services and Amenities in Developing Communities (Green Book)* in 1988. The intention was to optimise the provision of engineering infrastructure and services by ensuring that they are of sound quality and also acceptable (both financially and technologically) to the recipient communities. The *Guidelines for the Provision of Engineering Services and Amenities in Residential Township Development* was published next. It was completed in 1992, but, due to the historical political changes in the country at the time, it was only published in 1994. The publication became known as the *Red Book* because of the colour of its ring binder, as was the case with the *Blue Book* and the *Green Book*.

The effect of layout planning on the cost of providing engineering infrastructure and services became increasingly evident, and the guidelines evolved over time to acknowledge this. Subsequent to the publication of the first *Red Book* in 1994, South Africa experienced significant societal changes that resulted in a new set of human settlement planning and design challenges and opportunities. It became evident that the guidelines may have to be expanded to enhance its contribution to the development of sustainable and vibrant human settlements, as opposed to mere serviced townships. This necessitated the development of the second *Red Book*. The CSIR was commissioned by the (then) National Housing Board to coordinate the development of the document, and it was published in 2000. It was titled *Guidelines for Human Settlement Planning and Design*, which reflected a more integrated, holistic approach to settlement planning and design.

The 2000 version of the *Red Book* was the result of a collaborative effort by several government departments under the auspices of the (then) Department of Housing. Mutual concern for the quality of the built environment and the country's natural resources, as well as a common recognition of the role that human settlement planning and the provision of engineering services plays in its protection or destruction, was the catalyst for this multi-departmental cooperation.

The need for the guidelines to be revised and updated

The understanding of human settlements has evolved significantly internationally and locally during the past two decades. This, together with substantial shifts in priorities and values, prompted the Department of Human Settlements (DHS) to embark on a process to revise and update the 2000 *Red Book*. The intention was to develop a document that would give guidance on local responses to global challenges, especially climate change and its relation to the built environment, and to bring the theoretical approaches to settlement making in line with the latest research and current thinking as reflected in various government policies, programmes, frameworks and strategies.

Furthermore, technologies and processes developed in recent years needed to be incorporated into the guidelines, while the challenges facing South African society needed to be acknowledged and the opportunities highlighted.

The process to develop a new Guide

The DHS embarked on an extensive and inclusive process to produce a document that would provide practical neighbourhood planning and design guidance and contribute to the development of settlements that are vibrant, safe, integrated and inclusive. The CSIR, as the custodian of the Red Book, was responsible for the management of the process, the coordination of the various contributors, and the preparation of the final document.

The process to develop a new Guide involved an extensive consultation process, a range of assessments and studies, and the preparation of content by numerous specialists supported by various reviewers. The consultation process included semi-structured interviews with a wide range of role players including officials from relevant government departments and entities, municipal officials and councillors, academics, researchers, community-based organisations, non-government organisations, and private sector built environment professionals (e.g. engineers, urban designers, urban planners, architects and landscape architects).

A Project Steering Committee (PSC) was established to provide strategic guidance with respect to the approach to settlement planning, design and development that the Red Book should be advocating. It also played an advisory role regarding the philosophy and principles that should underpin the guidelines, as well as current and envisaged policy directions. The PSC comprised of individuals with appropriate experience representing a range of stakeholders, including the DHS and its entities, key government departments, civil society, the CSIR and councils for the various built environment professions.

Teams of specialists from the CSIR and various other organisations were assembled to prepare the content of the document. The different sections required teams with expertise in the fields of, amongst others, urban planning and design, architecture, landscape architecture and engineering. Each writing team was supported by a domain-specific Thematic Reference Group (TRG). The TRGs supported the authors by providing direction with respect to the information and guidance to be included in the different sections. They also had to ensure that the technical content is accurate and appropriate. The TRGs consisted of domain specialists from, for instance, relevant government departments, built environment practitioners, and recognised academics and researchers.

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A wide range of individuals and organisations were involved in one way or another in the development of *The Neighbourhood Planning and Design Guide*. The development process commenced in March 2015, and numerous people made contributions at different stages of the project. These individuals, and their affiliations at the time of their involvement, are listed below.

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Consultation process

Consultation sessions were held in all nine provinces and included a wide selection of organisations and entities representing various sectors. While it is not practically possible to list the names of all the individuals who participated in the consultation process, their valuable contributions are sincerely appreciated.

In total, more than 770 individuals were consulted, and almost 80 consultation sessions took place across South Africa. Organisations and entities that were consulted include local, district and metropolitan municipalities, national and provincial government departments, statutory bodies, Community-Based Organisations (CBOs), Non-Governmental Organisations (NGOs), private sector companies, professional bodies, and academic and research institutions. In addition, various events and platforms were used to raise awareness, as listed below.

Awareness-raising events and platforms

Smart and Sustainable Built Environment (SASBE) Conference 2015	December 2015, Pretoria
Habitat III Thematic Meeting on Informal Settlements	April 2016, Pretoria
National Spatial Planning and Land Use Management (SPLUM) Forum	May 2016, Kempton Park
Annual Conference of the Water Institute of Southern Africa (WISA)	May 2016, Durban
Department of Human Settlements and SALGA Round Table on Planning, Design and Development of Integrated Human Settlements	June 2016, Kempton Park
Department of Human Settlements - Internal Workshop	June 2016, Pretoria
South African Planning Institute (SAPI) Conference: Planning Africa 2016	July 2016, Johannesburg
National Human Settlements Conference	October 2016, Port Elizabeth
SPLUM Forum Working Group 2	October 2016, Pretoria
Department of Human Settlements Civil Society workshop	March 2017, Kempton Park
Habitat for Humanity Practitioners' Forum	June 2017, Cape Town
SALGA: Western Cape Human Settlements Working Group	August 2017, Cape Town
Council for the Built Environment	27 September 2017, Pretoria
SALGA Focus Group Workshop	May 2018, Pretoria
South African Planning Institute (SAPI) Conference: Planning Africa 2018	October 2018, Cape Town
National SPLUM Forum	November 2018, Kempton Park

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Structure of this Guide

This Guide is divided into two parts. Part I contains sections A to E, while sections F to O make up Part II. The sections are colour-coded for ease of navigation.

Part I: Setting the scene

This part contains background information that frames the environment within which the Guide will be applied. The term 'human settlement' is defined, the human settlement context in South Africa is briefly discussed and key global trends and challenges are highlighted. A vision for human settlements in South Africa is formulated based on international imperatives and the local regulatory environment. Against this background, the purpose, nature and scope of the Guide are explained.

In addition, the sphere of influence of this Guide is defined in terms of the phases involved in neighbourhood development projects. The positioning of this Guide within the broader regulatory environment is clarified, and the importance of adopting an integrated approach when implementing the Guide is emphasised. The factors to consider when applying the guidelines, including the application context and the type of development, are described. The need to involve all stakeholders in the planning and design process is emphasised and the importance of inter-disciplinary collaboration, community participation and co-production is explained.

Part II: Planning and design guidelines

A series of guidelines dealing with the planning and design of services and infrastructure is presented in this part. Practical information is provided regarding settlement layout, housing, social facilities, public open space, transportation, water, sanitation, stormwater, solid waste management, energy and a number of cross-cutting issues. The information in sections F to N is structured in the same format as follows:

- An **outline of the section** that also contextualises the theme of the section in relation to the other aspects addressed in the Guide.
- A discussion of **universal considerations**, which ensures that key aspects are considered from the outset. This includes a brief summary of the applicable regulatory environment, an outline of the key objectives to be strived for when applying the planning and design guidelines provided in the particular section. Furthermore, possible approaches and strategies that could be employed to achieve the objectives, as well as concepts and trends related to the theme of the section, are highlighted. Attention is also drawn to the contextual factors that should be considered regarding the type, nature and setting of the development project being implemented.
- **Planning considerations** are discussed next. Planning in this context means making decisions regarding the type and level of service that will be provided. To make informed decisions, a thorough understanding is required of the context within which the planned development will be implemented. This section outlines a range of factors that have to be considered before deciding on the type and level of service that will be provided and the associated systems and infrastructure that will have to be designed. It provides guidance that will assist in understanding what is needed, and what is available. Various options of the types and levels of service that could possibly be considered are discussed.
- Finally, **design considerations** are outlined. Detailed guidance is provided, explaining how to design the systems and infrastructure relevant to each section.

At the end of Part I and the end of sections F to O, a glossary and a list of acronyms and abbreviations are provided, as well as endnotes containing references, explanatory notes and acknowledgements.

Where information relevant to a particular discussion is provided in other sections of the Guide, those sections are cross-referenced to encourage an integrated approach to decision-making when applying the guidelines. More information regarding the application of the guidelines is provided in **Section C** and **Section D**.

Text boxes are used to emphasise some of the information provided in this Guide. The following symbols indicate the reason why the information is highlighted:

- 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

PART I: SETTING THE SCENE

- A The human settlements context
- B A vision for human settlements
- C Purpose, nature and scope of this Guide
- D How to use this Guide
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PART II: PLANNING AND DESIGN GUIDELINES

- F Neighbourhood layout and structure
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- H Housing and social facilities
- I Transportation and road pavements
- J Water supply
- K Sanitation
- L Stormwater
- M Solid waste management
- N Electrical energy
- O Cross-cutting issues
  - Planning and designing safe communities
  - Universal design

Section A
The Human Settlements Context

The Neighbourhood Planning and Design Guide

A.1 Human settlements

A human settlement, in essence, can be described as a place where people have settled down to live; a place where they carry out various activities as individuals or as a community, including working, socialising, shopping, relaxing and sleeping. Inevitably, the characteristics of different human settlements will vary, for instance with respect to size, location, structure, form, function and inhabitants.

A settlement typically includes the following components:

- The built environment, including houses, engineering infrastructure and facilities
- The natural environment, including vegetation, rivers, hills and valleys
- Services related to, for instance, healthcare, welfare, education, culture, recreation and administration
- The residents (people)

The term human settlement is all-encompassing and refers to anything from a small group of dwelling units to a village, town and city. It is not defined by size, function, setting (e.g. urban or rural) or other characteristics.

Photo credit: Chris Kirchhoff (R) - www.brandsouthafrica.com

Figure A.1: The term human settlement refers to anything from a small group of dwellings to a large city

According to the *Vancouver Declaration on Human Settlements (1976)*, human settlements "...mean the totality of the human community – whether city, town or village – with all the social, material, organizational, spiritual and cultural elements that sustain it".[1]

The nature and characteristics of human settlements are influenced by a range of factors. These factors could relate to the macro context, for instance country-specific aspects such as the country's geography, political systems, history or cultural heritage. They could also relate to local features such as topography, rivers, springs, hills and mountains, railway lines, roads, mining activities and harbours.

Many of these factors have influenced the nature and characteristics of South African cities, towns, villages and even neighbourhoods. Some of these factors – and the South African human settlement landscape in general – are briefly discussed in the next section.

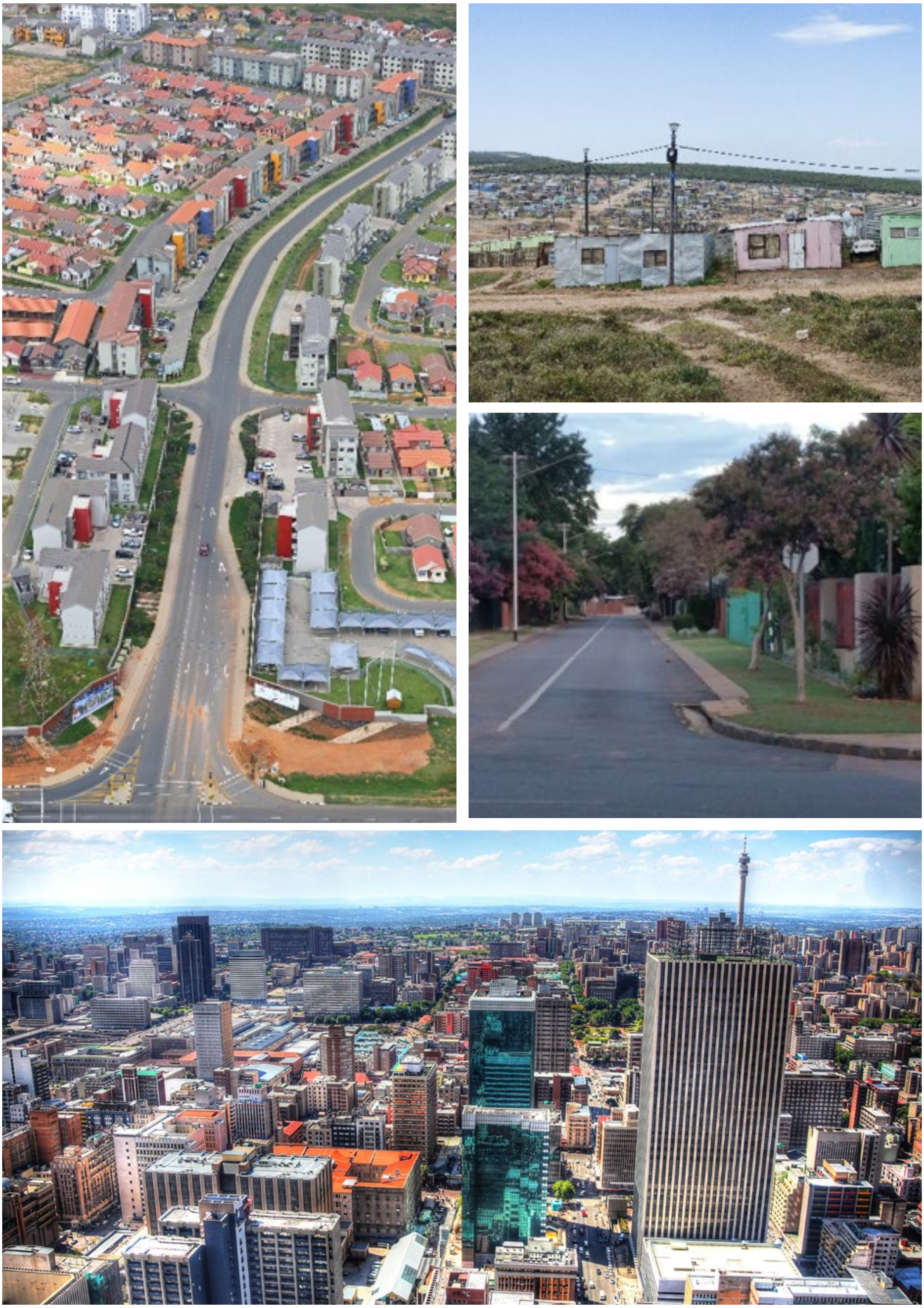

Figure A.2: The nature and characteristics of cities, towns, villages and neighbourhoods vary

A.2 Human settlements in South Africa

According to the National Development Plan 2030 (NDP), some aspects of the human settlement environment in South Africa have been transformed noticeably since 1994 when the first democratic elections were held. Encouraging trends include an increase in densities in a number of urban areas, the partial regeneration of certain inner cities, the provision of public transport infrastructure in some places[2] and the transformation of the racial composition of many previously predominantly white suburbs as a result of the growth of the black middle class.[3]

Notable changes in the character and racial composition of Central Business Districts (CBDs) and inner city areas of many cities and towns have occurred since 1994. These areas continue to experience an influx of predominantly black residents looking for employment opportunities or wanting to reside closer to their places of employment. Unfortunately, adequate accommodation is not always available, resulting in unacceptable living conditions due to overcrowding of residential buildings, especially blocks of flats and other rental accommodation. In some cases the physical environment in these areas has deteriorated considerably and businesses have relocated elsewhere. To meet the need of the changing consumer base, different types of businesses providing commercial, recreational and entertainment services have been established, including informal trading.[4]

In some cities and towns, formal economic activities have become more dispersed and less concentrated. Certain businesses relocate away from the traditional economic hubs such as the town or city centre to locations closer to the periphery where there may be less congestion, security may be better, land may be less expensive and access to major transport routes may be more convenient. In some cases, this resulted in a multi-centred, or polycentric, spatial form.[5]

Changes to other aspects of the space economy are also evident. For instance, the use of housing units (whether formal, informal, or in predominantly residential neighbourhoods) as businesses to generate income changes the character of neighbourhoods. Public spaces such as sidewalks and transport interchanges are furthermore often used by vendors to sell various products. These contributions to the so-called informal economy challenge conventional perceptions and realities about settlement economies.[6]

Figure A.3: Informal settlements and informal economic activity are features of many South African settlements

Informal settlements are a common feature of many South African towns and cities. In many cases they provide new migrants and the urban poor an affordable point of access into towns and cities. However, they are also associated with high degrees of physical and social vulnerability, which add to the challenges faced by residents and authorities. The upgrading of these settlements is often a contentious issue.[7]

In some cases, the country's urban landscape has been influenced by the prevalence of crime. The unacceptably high levels of violent crime, as well as the fear of crime, have contributed to the implementation of built environment interventions to address these concerns. Middle- to high-income neighbourhoods in particular are often characterised by high fences and walls, often supplemented by electric fences. In addition, public access to some neighbourhoods is restricted by means of street closures and access control mechanisms (Figure A.4). Various other forms of privately developed gated communities are becoming increasingly popular, varying in size from small townhouse complexes to expansive lifestyle or security estates. In some cases, these developments have a substantial impact on the structure and functioning of cities and towns, and it could be argued that they do not support current planning policies and strategies aimed at promoting integration.[8]

Figure A.4: Road closures and security estates influence the nature of the urban landscape

The results of planning principles and approaches that were directly influenced by the country's apartheid ideology are still visible in spatial patterns and in the form and structure of South African cities and towns. For decades, this ideology as well as the modernist approach to urban planning dominated the planning and design of settlements in South Africa, resulting in the legacy of racial segregation, poverty and exclusion from social and economic opportunities.[9] Spatial challenges also include sprawl, low-density and mono-functional (often fragmented) neighbourhoods.

Many parts of South African cities and towns – particularly those developed specifically for poor communities – are still characterised by a lack of adequate infrastructure, facilities and amenities, low levels of service and few or undesirable public spaces. These areas are often located on the periphery of cities and towns, and therefore residents generally have to travel long distances to and from their places of employment, shops and social, recreational, healthcare or other facilities. This negatively affects the quality of life of those living in these areas and has significant financial implications. It also increases pollution levels and results in the inefficient utilisation of resources.

"After the 1994 elections, Government committed itself to developing more liveable, equitable and sustainable cities. Key elements of this framework included pursuing a more compact urban form, facilitating higher densities, mixed land use development, and integrating land use and public transport planning, so as to ensure more diverse and responsive environments whilst reducing travelling distances. Despite all these well-intended measures, the inequalities and inefficiencies of the apartheid space economy, has lingered on."[10]

South African human settlements are inextricably linked to the country's socio-economic context. This means that poverty, unemployment, inequality, crime and violence and other challenges have an impact on the sustainability of cities and towns. In addition, global trends and challenges have to be considered, as outlined in the next section.

Photo credit: City of Cape Town (R, T)

Figure A.5: Spatial characteristics of South African settlements include sprawl, fragmentation and inequality

"A great deal of progress has been made since 1994, but South Africa is far from achieving the Reconstruction and Development Programme (RDP) goals of 'breaking down apartheid geography through land reform, more compact cities, decent public transport and the development of industries and services that use local resources and/or meet local needs'. Despite reforms to the planning system, colonial and apartheid legacies still structure space across different scales."[11]

A.3 Global trends and challenges

Climate change poses a significant threat to the planet and the people living on it. Human settlements where more and more people are living are particularly exposed to the consequences of climate change and are vulnerable to natural disaster risks.

The following challenges related to settlements resulting from climate change are listed in the *National Climate Change Response Policy*:[12]

- Climate change may exacerbate the problems caused by poor urban management. For example, poor stormwater drainage systems and urban-induced soil erosion result in flash flooding. Increased storm intensity due to climate change would exacerbate such problems.
- Cities are particularly vulnerable to climate change because they are slow to adapt to changes in the environment and they have entrenched dependencies on specific delivery mechanisms for critical services.
- The effective management of the interface between urban residents and their surrounding environment producing sustainable social-ecological systems needs to the addressed. Similarly, the concept of climate resilience in the context of urban social-ecological systems needs to be further developed.
- South Africa's cities still reflect apartheid planning with the poorest communities tending to live far away from services and employment. Our cities are relatively spread out and these two factors contribute to increased transport emissions.
- Water demand in urban centres is growing rapidly, placing undue stress on water supply systems. Investment in waste water treatment works has not remained in line with the growth in demand and use.
- Informal settlements are vulnerable to floods and fires, exacerbated by their location in flood- or ponding-prone areas and on sand dunes; inferior building materials; and inadequate road access for emergency vehicles.
- Cities and dense urban settlements consume large amounts of energy.

Informality as it relates to settlement and housing form, the way income is generated and the way in which people live in and interact with cities and towns is a worldwide phenomenon that seems to become more and more prevalent in the Global South. Informality is often associated with illegitimate behaviour and with marginalised people and communities, but arguments have been made for it to be acknowledged and accommodated in the planning and design of cities.

Rapid urbanisation is a global phenomenon, and the situation is no different in Africa and South Africa. It is predicted that Africa's urban population will increase from approximately 1.23 billion people in 2015 to 2.5 billion people in 2050 (60% of the total population). According to estimates by the United Nations, more than 71% of the South African population will live in urban areas by 2030. Urbanisation places added strain on cities and towns that struggle to deal with the demands already placed on them. To reduce the impact of urbanisation, many cities and towns internationally are striving to become more resource efficient so as to be more sustainable and competitive. Unfortunately it seems South African cities and towns have not yet fully embraced this notion.[13]

Section B
A vision for human settlements

The Neighbourhood Planning and Design Guide

B.1 International imperatives

Since 2015, member states of the United Nations have been expected to frame their agendas and political policies for a period of 15 years according to "Transforming our World: the 2030 Agenda for Sustainable Development". Commonly referred to as the 17 Sustainable Development Goals, it is a "plan of action for people, planet and prosperity".[14] Many of the goals are relevant to human settlements, but Goal 11 deals specifically with sustainable cities and communities: "Make cities and human settlements inclusive, safe, resilient and sustainable."[15]

At the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) held in Quito, Ecuador, in October 2016, a document known as the New Urban Agenda was adopted. The purpose of this agenda is to guide national and local policies on the growth and development of cities up to 2036. It shares "...a vision of cities for all, referring to the equal use and enjoyment of cities and human settlements, seeking to promote inclusivity and ensure that all inhabitants, of present and future generations, without discrimination of any kind, are able to inhabit and produce just, safe, healthy, accessible, affordable, resilient and sustainable cities and human settlements to foster prosperity and quality of life for all".[16]

In *The New Urban Agenda*[17], human settlements are envisaged that:

- Fulfil their social function, including the social and ecological function of land, with a view to progressively achieving the full realization of the right to adequate housing as a component of the right to an adequate standard of living, without discrimination, universal access to safe and affordable drinking water and sanitation, as well as equal access for all to public goods and quality services in areas such as food security and nutrition, health, education, infrastructure, mobility and transportation, energy, air quality and livelihoods;
- Are participatory, promote civic engagement, engender a sense of belonging and ownership among all their inhabitants, prioritize safe, inclusive, accessible, green and quality public spaces that are friendly for families, enhance social and intergenerational interactions, cultural expressions and political participation, as appropriate, and foster social cohesion, inclusion and safety in peaceful and pluralistic societies, where the needs of all inhabitants are met, recognizing the specific needs of those in vulnerable situations;
- Achieve gender equality and empower all women and girls by ensuring women's full and effective participation and equal rights in all fields and in leadership at all levels of decision making, by ensuring decent work and equal pay for equal work, or work of equal value, for all women and by preventing and eliminating all forms of discrimination, violence and harassment against women and girls in private and public spaces;
- Meet the challenges and opportunities of present and future sustained, inclusive and sustainable economic growth, leveraging urbanization for structural transformation, high productivity, value-added activities and resource efficiency, harnessing local economies and taking note of the contribution of the informal economy while supporting a sustainable transition to the formal economy;
- Fulfil their territorial functions across administrative boundaries and act as hubs and drivers for balanced, sustainable and integrated urban and territorial development at all levels;
- Promote age- and gender-responsive planning and investment for sustainable, safe and accessible urban mobility for all and resource-efficient transport systems for passengers and freight, effectively linking people, places, goods, services and economic opportunities;
- Adopt and implement disaster risk reduction and management, reduce vulnerability, build resilience and responsiveness to natural and human-made hazards and foster mitigation of and adaptation to climate change;
- Protect, conserve, restore and promote their ecosystems, water, natural habitats and biodiversity, minimize their environmental impact and change to sustainable consumption and production patterns.

From an African perspective, a strategic framework for the socio-economic transformation of the continent was developed by the African Union Commission. “Agenda 2063 – The Africa we want” outlines a number of aspirations. It includes an Africa where “[c]ities and other settlements are hubs of cultural and economic activities, with modernized infrastructure, and people have access to affordable and decent housing including housing finance together with all the basic necessities of life such as, water, sanitation, energy, public transport and ICT”.[18]

These international goals and agendas inform the actions taken to improve South African human settlements and complement the aims and objectives as described in the next section.

B.2 South African settlements – the policy environment

Various policies, strategies, frameworks, plans and other documents highlight the principles to be applied when developing human settlements and describe a range of qualities and characteristics that cities, towns and neighbourhoods should strive to display. Collectively, they describe various aims and objectives to be achieved and define a vision for human settlements in South Africa.

Key elements of selected documents are briefly highlighted below.

(i) National Development Plan 2030: Our Future – Make it Work

The National Development Plan 2030 (NDP) provides a long-term vision for the country and defines a desired destination, specifically aiming to eliminate poverty and reduce inequality by 2030. In Chapter 8 it explicitly addresses the transformation of human settlements and the national space economy. The NDP foresees that planning will be "...guided by a set of normative principles to create spaces that are liveable, equitable, sustainable, resilient and efficient, and support economic opportunities and social cohesion".[19] It also expects there to be meaningful and measurable progress in creating more functionally integrated, balanced and vibrant urban settlements by 2030.[20] It proposes a strategy that would "...address the apartheid geography and create the conditions for more humane – and environmentally sustainable – living and working environments".[21]

"All new developments should enhance the ideal of creating vibrant, diverse, safe and valued places."[22]

The NDP supports and promotes a range of actions and objectives, including densification, informal settlement upgrading on suitably located land, improving transport, inner-city regeneration and neighbourhood safety. It encourages the design of cities and towns for long-term resilience and flexibility, and gives attention to citizen vulnerability and safety in response to economic uncertainties and climate change.

The following overarching principles for spatial development are identified in the NDP:[23]

- **Spatial justice**. The historic policy of confining particular groups to limited space, as in ghettoisation and segregation, and the unfair allocation of public resources between areas, must be reversed to ensure that the needs of the poor are addressed first rather than last.
- **Spatial sustainability**. Sustainable patterns of consumption and production should be supported, and ways of living promoted that do not damage the natural environment.
- **Spatial resilience**. Vulnerability to environmental degradation, resource scarcity and climatic shocks must be reduced. Ecological systems should be protected and replenished.
- **Spatial quality**. The aesthetic and functional features of housing and the built environment need to be improved to create liveable, vibrant and valued places that allow for access and inclusion of people with disabilities.
- **Spatial efficiency**. Productive activity and jobs should be supported, and burdens on business minimised. Efficient commuting patterns and circulation of goods and services should be encouraged, with regulatory procedures that do not impose unnecessary costs on development.

(ii) Integrated Urban Development Framework

The Integrated Urban Development Framework (IUDF) is the South African government's policy framework that intends to guide the future growth and management of urban areas. Its purpose is to steer urban growth towards a sustainable growth model of compact, connected and coordinated cities and towns so as to achieve the intended outcome of spatial transformation.

The IUDF aims to create a shared understanding across government and society regarding the creation of inclusive, resilient, resource-efficient and liveable urban settlements, given the unique conditions and challenges facing South Africa's cities and towns.

> "Prosperous and liveable cities are urban spaces where citizens feel safe from violence and crime, and can take full advantage of the economic, social and cultural opportunities offered by cities."[24]

The IUDF discusses nine policy levers that should contribute to the restructuring of urban space and effect the transformation of human settlements. These levers are summarised below.[25]

- **Integrated urban planning and management**
  Cities and towns that are well planned and efficient, and so capture the benefits of productivity and growth, invest in integrated social and economic development, and reduce pollution and carbon emissions, resulting in a sustainable quality of life for all citizens.
- **Integrated transport and mobility**
  Cities and towns where goods and services are transported efficiently, and where people can walk, cycle and use different transport modes to access economic opportunities, education institutions, health facilities and places of recreation.
- **Integrated sustainable human settlements**
  Cities and towns that are liveable, integrated and multi-functional, in which all settlements are well connected to essential and social services, as well as to areas of work opportunities.
- **Integrated urban infrastructure**
  Cities and towns that have transitioned from traditional approaches to resource-efficient infrastructure systems that provide for both universal access and more inclusive economic growth.
- **Efficient land governance and management**
  Cities and towns that grow through investments in land and property, and that provide income for municipalities, which allows for further investments in infrastructure and services, and results in inclusive, multi-functional urban spaces.
- **Inclusive economic development**
  Cities and towns that are dynamic and efficient, foster entrepreneurialism and innovation, sustain livelihoods, enable inclusive economic growth, and generate the tax base needed to sustain and expand public services and amenities.
- **Empowered active communities**
  Cities and towns that are stable, safe, just and tolerant, and that respect and embrace diversity, equality of opportunity and participation of all people, including disadvantaged and vulnerable groups and persons.
- **Effective urban governance**
  Cities and towns that have the necessary institutional, fiscal and planning capabilities to manage multiple urban stakeholders and intergovernmental relations, in order to build inclusive, resilient and liveable urban spaces.

- **Sustainable finances**
  Cities and towns that are supported by a fiscal framework that acknowledges the developmental potential and pressures of urban spaces, that manage their finances effectively and efficiently, and that are able to access the necessary resources and partnerships for inclusive urban growth.

The nine policy levers are supported by, and must be read in conjunction with, the following cross-cutting issues:

Rural-urban interdependency - recognising the need for a more comprehensive, integrated approach to urban development that responds to both the urban and the rural environments.

Urban resilience - disaster risk reduction and mitigation interventions in the planning and management of urban areas.

Urban safety - an essential ingredient for creating liveable and prosperous cities, particularly safety in public spaces.

A vision for urban areas according to the IUDF[26]

Liveable, safe, resource-efficient cities and towns that are socially integrated, economically inclusive and globally competitive, where residents actively participate in urban life.

Strategic goals outlined in the IUDF[27]

The following four strategic goals contribute to achieving the transformative vision of restructured urban spaces and compact, connected cities and towns:

- **Spatial integration** – To forge new spatial forms in settlement, transport, social and economic areas.
- **Inclusion and access** – To ensure people have access to social and economic services, opportunities and choice.
- **Growth** – To harness urban dynamism for inclusive, sustainable economic growth and development.
- **Governance** – To enhance the capacity of the state and its citizens to work together to achieve spatial and social integration.

(iii) Comprehensive Plan for the Development of Sustainable Human Settlements

The Comprehensive Plan for the Development of Sustainable Human Settlements, also known as Breaking New Ground (BNG), promotes a move away from a "...commoditised focus of housing delivery toward more responsive mechanisms which addresses the multi-dimensional needs of sustainable human settlements".[28] It advocates that, rather than focusing on the provision of basic shelter, more efficient and sustainable human settlements should be developed. It encourages higher densities, mixed land use, the integration of land use and public transport planning and a more compact urban form to support the creation of more diverse and responsive environments and reduced travelling distances.

BNG envisions that present and future inhabitants of human settlements should "...live in a safe and secure environment and have adequate access to economic opportunities, a mix of safe and secure housing and tenure types, reliable and affordable basic services, educational, entertainment and cultural activities and health, welfare and police services".[29]

"Sustainable human settlements refer to well-managed entities in which economic growth and social development are in balance with the carrying capacity of the natural systems on which they depend for their existence and result in sustainable development, wealth creation, poverty alleviation and equity."[30]

(iv) National Climate Change Response White Paper

The National Climate Change Response White Paper outlines South Africa's commitment to making a fair contribution to stabilising global greenhouse gas (GHG) concentrations in the atmosphere and to protecting the country and its people from the impacts of inevitable climate change.

The National Climate Change Response White Paper "...presents the vision for an effective climate change response and the long-term transition to a climate-resilient, equitable and internationally competitive lower-carbon economy and society – a vision premised on Government's commitment to sustainable development and a better life for all".[31]

Section 5 of the White Paper[32] outlines responses to climate change challenges linked to specific sectors, including the human settlements sector. Proposed responses include the following:

- Investigate how to leverage opportunities presented by urban densification to build climate-resilient urban infrastructure and promote behavioural change as part of urban planning and growth management.
- In the implementation of low-cost housing, ensure access to affordable lower-carbon public transport systems, incorporate thermal efficiency into designs and use climate-resilient technologies.
- Encourage and develop water sensitive urban design to capture water in the urban landscape and to minimise pollution, erosion and disturbance.
- Ensure that land use zoning regulations are enforced and that urban land use planning considers the impacts of climate change and the need to sustain ecosystem services when considering settlements and infrastructure development proposals.

B.3 A vision for South African settlements

In the discussions so far, a range of key principles, aims and objectives were identified that are intended to guide the development of human settlements in South Africa. Various qualities have also emerged that need to characterise cities and towns to improve the living environments for all residents and create the transformed settlement landscape envisioned for the country. Against this background, the following could be regarded as a vision for human settlements:

Sustainable human settlements are liveable, vibrant, diverse, resilient and valued; they are socially integrated, economically inclusive places where residents feel safe and in which economic growth and social development are in balance with the carrying capacity of the natural systems on which they depend for their existence.

It is important to recognise that the country has many types of cities and towns, with different roles and requirements, and therefore the vision has to be interpreted in response to the context and pursued in a differentiated and locally relevant way.[33]

Section C

Purpose, nature and scope of this Guide

The Neighbourhood Planning and Design Guide

C.1 Aim and objectives of this Guide

The overall aim of this Guide is to give effect to the vision for South African human settlements outlined in **Section B.3** by providing guidance regarding neighbourhood-level planning and design. The Guide is intended to address some of the challenges and assist in achieving the aims and objectives discussed in sections A and B, while it also supports South Africa's efforts to achieve the Sustainable Development Goals and pursue the visions outlined in the New Urban Agenda and Agenda 2063 (see **Section B1**).

To accomplish this, the objectives of this Guide are to:

- indicate the qualities that should be sought in South African settlements and neighbourhoods, and to provide practical guidance on how these qualities can be achieved through the implementation of physical development projects;
- inform neighbourhood-level decision-making related to the planning and design of the various physical components of human settlements; and
- encourage integrated settlement and neighbourhood planning and design, to promote sound urban planning and design principles and to assist in improving the efficiency of engineering services and infrastructure.

Figure C.1: Neighbourhoods are the 'building blocks' of settlements and differ in nature and character

C.2 Nature and scope of this Guide

The purpose of this Guide is to provide practical information related to the planning and design of the range of services and infrastructure typically provided as part of a neighbourhood development project. The application of the guidelines should ultimately result in the delivery of infrastructure and services that are effective and efficient and that contribute to the realisation of the vision for human settlements as outlined in **Section B.3.**

> The Guide is primarily intended to inform the decisions made as part of a project aimed at developing a specific part of a city or town (referred to as a 'neighbourhood' in this Guide). The exact definition of a neighbourhood is not of critical importance when applying this Guide. Neighbourhoods are not constructs such as provinces and countries, and it is not always possible or practical to clearly delineate a neighbourhood. It may also not necessarily be helpful to establish definite boundaries that clearly exclude and include certain areas, services or facilities.
>
> This document is not intended as a planning guide for an entire city or town, but by applying the guidelines at a neighbourhood level, the aims and objectives to be achieved at a city or town level should be supported and reinforced.

The guidelines are aimed largely at neighbourhood-level services and infrastructure. Bulk services and amenities such as main water supply pipelines, outfall sewers, treatment works, landfills, freeways and so forth are considered beyond the scope of this Guide. For the most part it also does not include detailed site and building-level information.

The Guide allows for differences in context, for instance urban, rural and peri-urban; and also for various geotechnical and topographical conditions. The guidelines are applicable to different types of developments including greenfield, brownfield and informal settlement upgrading projects. (See **Section D.3**.)

It is essential to keep the following in mind:

- The guidelines are not prescriptive and require interpretation informed by the application context. They should not be regarded as minimum standards or regulations. Guidelines in general are intended to assist decision-making, whereas standards are normally considered as measurable, enforceable limits. Both the rigid application of guidelines and the setting of inappropriate standards often have the opposite effect to what was intended.
- This Guide is not a substitute for professional or practical experience and it recognises the importance of professional responsibility where applicable.
- Judgement should always be exercised based on the actual circumstances. The Guide includes information about good practices and aims to encourage innovation and creativity.

C.3 The sphere of influence of this Guide

As outlined above, the intention with the guidelines is to assist those involved in the various aspects of a neighbourhood development project with making informed planning and design decisions. Development projects involve numerous phases that can be spread over many years, even decades. The typical phases of a conventional development project are indicated in Figure C.2. Since the types of development projects vary, the phases as indicated will vary, as will the role players involved in the process. Some projects are developer driven, aimed at middle- to higher-income residents and require private sector funding. Other projects are aimed at low-income communities and involve the participation of government departments and entities, community-based organisations and non-government organisations. They are usually partly dependent on government funding in the form of grants and subsidies. (The processes to be followed for these types of project are outlined in the *Housing Project Process Guide* developed by the Department of Human Settlements.[34])

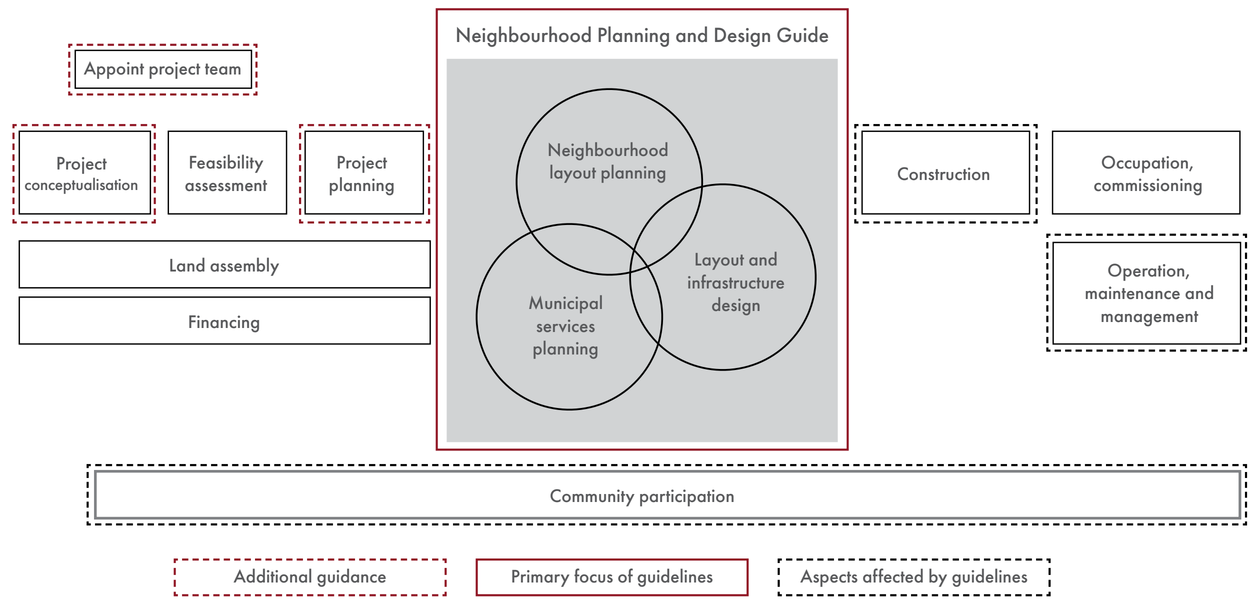

Figure C.2: The typical phases of a conventional development project – sphere of influence of this Guide

As indicated in Figure C.2, the sphere of influence of this Guide is confined to specific aspects of the development process. Certain phases need to be completed before the issues addressed in this Guide become relevant, and some phases will be implemented after the phases that involve the application of the guidelines This Guide is primarily focused on the phases involving neighbourhood layout planning, municipal services planning and layout and infrastructure design. However, the Guide could also be of practical use during the conceptualisation and project planning phases, and also when appointing a project team. It could provide guidance with the preparation of a brief (terms of reference), the development of a proposal in response to the brief, the evaluation of proposals, as well as the subsequent planning and design of the development. Despite this specific focus of the Guide, it is important to remember that decisions made during these phases will have an impact on certain aspects of the community participation process, the construction of the development as well as the operation, maintenance and management of the infrastructure.

The success of a development project is dependent on sound decision-making during all phases of the project, and the information provided in this Guide will not be able to undo the impact of poor decisions made during the early stages of a project. In particular, the location of the project and the characteristics of the land to be developed should be considered carefully. Finding suitable land could be difficult, and land assembly is often a challenging undertaking that could take several years.

Suitable land – a critical aspect of a development project

A key decision that needs to be made at the outset relates to the location and characteristics of the intended development site. Depending on the type of project, some or all of the following factors need to be taken into consideration:

- The location of the land may have to align with national and provincial strategic objectives as outlined in (for instance) Spatial Development Frameworks and it may have to adhere to spatial targeting requirements.
- The location of the land may also have to align with local development objectives as outlined in (for instance) the relevant Integrated Development Plan (IDP), specifically the Spatial Development Framework (SDF) and the Built Environment Performance Plan (BEPP).
- The potential for integrating the development into the existing settlement (for instance, access to transport, economic activities, amenities and services).
- The physical characteristics of the land, including the topography, geology, size and shape.
- The local context, for instance whether the setting is rural, urban or peri-urban, the nature of the immediate surrounding environment and neighbourhoods, demographic characteristics, etc.
- Zoning and land use, land claims, servitudes, ownership and other legal aspects.

More information is available in the *Guidelines for the identification of well-located land for human settlements.*[35]

C.4 Target users

This Guide contains information relevant to all built environment practitioners, particularly those involved in the planning and design of human settlements. It is intended to provide support to both the private and public sectors. Potential users of the guidelines include the following:

- Built environment professionals and practitioners, including engineers (civil, transportation, electrical, etc.), urban planners, architects, landscape architects, urban designers, etc.
- Active citizens and community groups involved in people-driven housing development initiatives.
- Decision-makers, influencers and those who are required to develop policy, including local government councillors.
- Residents (communities) and others who need information that will enable them to better understand the consequences of decisions related to the provision of services and infrastructure.
- Tertiary institutions, particularly students and lecturers involved in the built environment professions.

Different types of readers would use the information for different reasons, and in some cases only those with specialist knowledge and experience would be able to interpret and apply some of the guidelines. However, the information is presented in a way that is as accessible and user-friendly as possible.

"One of the most valuable contributions over the next five years is to build the capabilities for effective spatial decision making and implementation. These capabilities are required in local, provincial and national government, educational and research institutions, the spatial professions such as planning, urban design and architecture and society at large."[36]

Section D
How to use this Guide

The Neighbourhood Planning and Design Guide

D.1 An integrated approach

The success of this Guide is dependent on the integration of the different aspects addressed in it when applying the guidelines in an actual development project. This means that when decisions are taken about one aspect of the proposed development, the implications these decisions may have on other aspects should be carefully considered. It is vital that the different sections of this Guide are not applied in isolation, but that the relationships between the different aspects dealt with in different sections are taken into account. A fundamental principle to keep in mind is collaboration, and, linked to it, effective communication. These principles are discussed in more detail in **Section E** (Working together).

When applying this Guide, cognisance should be taken of a range of acts, policies, frameworks and strategies. Since the Guide is aimed at project-level decision-making, specific attention should be paid to related guidelines, regulations, codes, norms and standards as illustrated in Figure D.1.

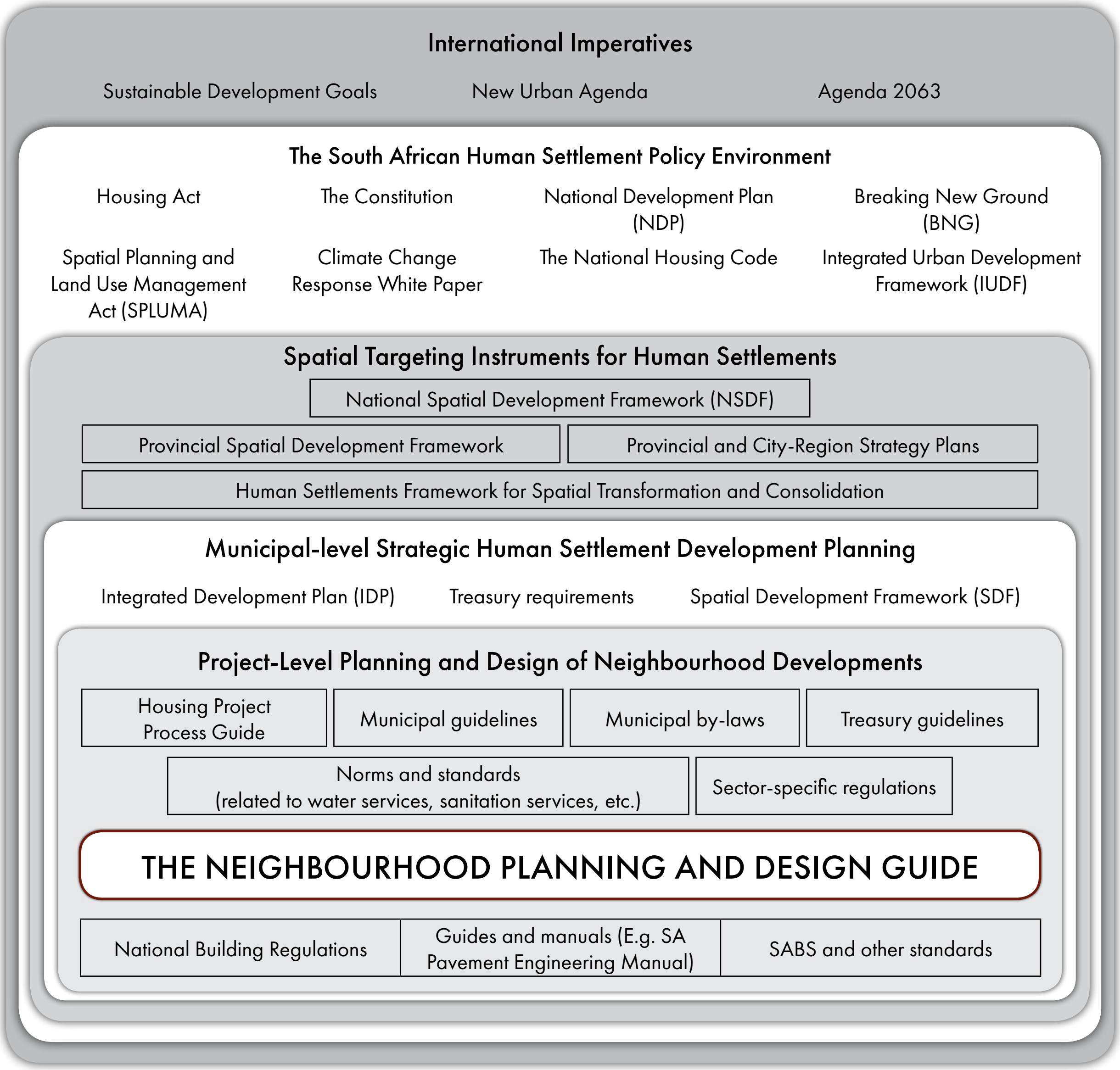

Figure D.1: Positioning of this Guide within the broader regulatory environment

D.2 A context-specific approach

Neighbourhood development projects are influenced by, and should be responsive to, their implementation context, for instance the location of the development and the nature of the land to be developed. The context of an informal settlement upgrading project would for example differ substantially from that of a greenfield development, and a greenfield development would be planned and designed differently when located in an urban area as opposed to a rural area. It is therefore important to carefully consider the context when applying this Guide.

Another factor that needs to be considered relates to the funding source and mechanism used to implement the development project. Projects associated with any of the housing assistance programmes and subsidy instruments outlined in the Housing Code of the National Department of Human Settlements need to satisfy the requirements as described in the Code. These requirements have to be considered in conjunction with the information provided in this Guide.

Developments associated with government housing assistance programmes and subsidies

The information provided in this Guide supports the objectives of the various assistance programmes and subsidy instruments included in the Housing Code.[37] The priority programmes and subsidies are revised from time to time, but they could include the following:

- **Integrated Residential Development Programme (IRDP)**
  The intention with this programme is to facilitate social, economic and spatial integration. It allows for the acquisition of land, servicing of stands for a variety of land uses including commercial, recreational, schools and clinics, as well as residential stands for low, middle and high-income groups.
- **Upgrading of Informal Settlement Programme (UISP)**
  This programme aims to improve the living conditions of people living in informal settlements by providing access to basic services and a choice of housing tenure options (including rental and options to buy).
- **Social Housing Programme**
  This programme allows for the provision of affordable rental accommodation, managed by social housing institutions, through a combination of government grants, private sector funding and equity.

Other programmes and subsidies include the Rural Subsidy (Communal Land Rights), the Provision of Basic Social and Economic Facilities Programme, the Individual Subsidy Programme, the Enhanced People's Housing Process Programme and the Farm Residents Housing Programme.

The context is determined by a range of factors that are generally linked to the type of development and the location or setting of the development, as briefly discussed below. These factors should be considered in more detail when applying the guidelines provided in Part II of this Guide, and therefore they are again referred to in sections F to N.

D.2.1 Type of development

The type of development relates to the nature of the particular site where development will occur. Development projects are most commonly categorised as greenfield, brownfield or informal settlement upgrading.

D.2.1.1 Greenfield development

A greenfield site is a vacant piece of land that has never been developed (built on). It could include agricultural land, open space (public or private), or natural unspoilt environments such as grasslands or forests. Greenfield sites could be located within the urban environment, adjacent to urban boundaries or in rural settings.

A greenfield development has certain advantages and disadvantages. A greenfield project may allow for more flexibility with respect to the planning and design of the development, and it could also unlock the potential of an entire area, resulting in new economic, housing and recreational opportunities. The layout and structure of the proposed development is not constrained by the existing built environment and existing buildings do not have to be demolished or somehow incorporated into the new development.

However, greenfield sites may not always have direct access to services such as water, sanitation, electricity and roads. This could have financial implications that should be taken into consideration when the development is planned. Furthermore, the ongoing consumption of undeveloped land, in particular productive agricultural land and green open space, is a serious concern. It contributes to the depletion of food production areas, increases motor vehicle usage and pollution, and may require additional expensive engineering services and infrastructure that may place an additional burden on municipal service delivery.

Care should be taken to ensure that a greenfield development does not enhance the negative characteristics of South African settlements as mentioned in Section A.2. If located on the periphery of a town or city, such developments could amplify the inequalities and inefficiencies of a city or town by (for instance) increasing travel distances to and from the residents' places of employment, shops and social, recreational, healthcare or other facilities. Special efforts should be made to ensure that the new development enhances spatial and social integration and economic inclusivity, and to create a positively performing neighbourhood as described in Section F.2.2.

Photo credit: City of Cape Town

Figure D.2: Example of a greenfield site

D.2.1.2 Brownfield development

A brownfield site refers to an area with existing infrastructure (buildings, roads and municipal services) that has the potential for further development, i.e. expansion, upgrading, renovation and/or rezoning. Brownfield sites could be defined as follows:

- Abandoned, dormant or underused industrial or commercial areas that could be transformed into residential or mixed-use neighbourhoods
- Town or city centres that need to be transformed or adapted to meet changing requirements
- Run-down neighbourhoods that have the potential to be revitalised
- Existing residential or mixed-use neighbourhoods that present the opportunity for sites to be subdivided and, if required, rezoned

A brownfield project could take on several forms. It could involve the total redevelopment of an area and the upgrading of existing infrastructure, or the installation of new infrastructure. It could also involve the upgrading of an area, including the renovating, repurposing or demolishing of existing buildings or areas (e.g. inner-city upgrading programmes) and it could involve infill developments on patches of vacant or underutilised land in a built-up area.

Photo credit: SSI Group

Figure D.3: Example of a development on a brownfield site

A brownfield development may have clear benefits, including potential savings because some bulk services may already be available. It is a more efficient way of using land and other resources; it could possibly have access to existing services and transport networks; or it may address urban decay. Brownfield projects could also contribute to the preservation of heritage sites and buildings, and the revitalisation of historic sites. The redevelopment of certain areas could sometimes act as a catalyst for the redevelopment of neighbouring areas and lead to a general enhancement of the surrounding area.

However, brownfield developments could also be costly and time consuming. Brownfield sites may be contaminated from previous uses, especially industrial, which could require rehabilitation of the site to remove all contaminants such as oil, asbestos, chemicals and other pollutants. Since residents, businesses and visitors would have to be consulted as part of the development process, their concerns could negatively influence or delay the proposed development. Existing infrastructure such as buildings, roads and engineering services could further restrict the design of the development. The redevelopment of certain neighbourhoods could lead to the gentrification of the area and thus force low-income residents to leave their homes, their community, their family and employment.

D.2.1.3 Informal settlement upgrading

Informal settlements are defined in a number of ways. According to Statistics South Africa, an informal settlement is "...an unplanned settlement on land which has not been surveyed or proclaimed as residential, consisting mainly of informal dwellings (shacks)".[38] They define an informal dwelling as "...a makeshift structure not approved by a local authority and not intended as a permanent dwelling".[39]

The National Housing Code of 2009[40] outlines several features that characterise informal settlements, including the following:

- **Illegality and informality**. Settlements are usually on unproclaimed land, or occupied without permission of the landowner (whether public or private).
- **Inappropriate locations**. Many settlements are located in marginal sites where development is inappropriate or even dangerous. These include sites on unsuitable geological conditions (such as dolomite), unsuitable topography (for example, steep slopes at risk of landslip or sites within flood lines), near heavy industrial infrastructure (such as mine dumps, slimes dumps or within smell zones) or within water, gas or electricity servitudes.
- **Restricted public and private sector investment**. Informal settlements typically have no or only rudimentary levels of services (such as water, sanitation and waste collection). Private enterprises rarely rise above the levels of survivalist activities, spaza shops and the like. The insecure status of informal settlements, coupled with low levels of public investment and lack of tenure, discourages households from investing in their shelter.

Figure D.4: Examples of informal settlement upgrading

The upgrading of informal settlements is a key component of the government's endeavours to deliver housing. Targeted programmes that have been established to support upgrading initiatives include the National Upgrading Support Programme (NUSP) and the UISP. The intention with these programmes is to support the provision of basic services (including water and sanitation) and security of tenure, while also empowering communities. A range of methods can be employed to provide housing, including self-build, the People's Housing Process, social housing, affordable rental or utilising individual or consolidation subsidies.

A staged process is encouraged, involving the incremental improvement of the quality of life through the provision of services and tenure. As far as possible, in-situ upgrading processes are preferred to minimise the need to relocate residents, thereby disrupting existing structures and community cohesion. Some informal settlements may appear to be unstructured and lack order, but the communities are often well organised and have support mechanisms and regulating structures in place. In certain cases, in-situ upgrading may not be an option, for instance when the location poses a threat to the health and lives of the residents. (See the reference to inappropriate locations in Section D.2.1.3.)

Despite the emphasis on in-situ upgrading, some local authorities and practitioners find it particularly challenging. Comprehensive support is provided in the form of a Resource Kit that is available on the NUSP website.[41]

Informal settlement upgrading according to the National Upgrading Support Programme (NUSP)[42]

There is a strong recognition that informal settlement upgrading is a social process, involving people who already inhabit the land and who therefore have to be partners in the upgrading process. This aspect is called co-production. This means that informal settlement communities need to be actively engaged at key levels in the formulation of a strategy and project plans.

The underlying philosophy of incremental informal settlement upgrading is as follows:

- Informal settlement residents have nowhere else to go and have found a way to make a living where they currently are.
- It is best to incrementally build on what they have already done themselves.
- By building on what people have done and listening to what they need, people's lives can best be improved.
- In this way, they can be integrated into the town or city.
- This means residents are partners in the upgrading process and stakeholders in the town or city.

D.2.2 The setting/location of the planned development

The setting of a development relates to the nature of the broader area within which it will be located. The setting is generally categorised as urban, peri-urban or rural.

D.2.2.1 Urban

The urban environment typically includes metropolitan areas, cities and towns. As such, the characteristics of different urban areas could vary substantially. The features of one part of a city or town could also differ significantly from those of other parts of the same city or town. Cities and towns consist of various parts, including central business districts, residential suburbs, informal settlements, and what used to be referred to as townships. These areas differ with respect to population and built environment density, as well as the availability and level of services and infrastructure.

In general, urban areas provide the settings for greenfield, brownfield and informal settlement upgrading projects. Cities and towns can provide opportunities for brownfield developments, including inner-city regeneration projects, the repurposing of buildings and the redevelopment or densification of residential neighbourhoods and abandoned industrial areas. When planning and designing these types of projects, the condition and capacity of existing services and infrastructure should be carefully considered.

Photo credit: Graeme Williams (R and B) - www.brandsouthafrica.com

Figure D.5: Examples of urban settings

D.2.2.2 Peri-urban

Peri-urban refers to the transitional space between rural and urban areas. This space becomes increasingly significant and contested as the process of urbanisation occurs and cities and towns continue to expand. The boundary line between rural, peri-urban and urban is not well defined and can therefore change rapidly. Because of this, municipalities find it difficult to manage urban sprawl. In some cases an urban edge is established to contain growth within a certain boundary. Land in peri-urban areas is often less expensive than urban land, and it is therefore popular for low-density greenfield development projects, which contribute to the urban sprawl phenomenon. Peri-urban areas often provide the settings not only for middle-income cluster complexes and high-income lifestyle estates, but also for informal settlements.

Photo credit: Durbanville Wine Valley (R) - www.brandsouthafrica.com


Figure D.6: Examples of peri-urban settings

D.2.2.3 Rural

Rural areas are usually sparsely populated and located outside the limits of a city or town. They include rural villages and small towns, dense rural settlements and dispersed settlements. The approach to the planning and design of neighbourhood development projects in rural towns is often similar to the approach taken in more urbanised areas. However, more sparsely populated rural areas and villages may have particular characteristics that require a less conventional approach. Factors that need to be considered include land ownership and tenure, especially since land may be communal property and under the control of traditional leaders.

Photo credit: Graeme Williams (L) - www.brandsouthafrica.com


Figure D.7: Examples of rural settings

D.3 A structured decision-making approach

D.3.1 A decision-making framework

The information provided in each of the different sections of Part II of this Guide is presented systematically to ensure that various factors that could potentially influence decisions are considered. The different sections deal with the following themes:

- Neighbourhood layout and structure
- Public open space
- Housing and social facilities
- Transportation and road pavements
- Water supply
- Sanitation
- Stormwater
- Solid waste management
- Electrical energy

The last section of Part II deals with two cross-cutting issues, namely planning and designing safe communities and universal design. Where applicable, these issues should be considered when making decisions related to each of the themes.

Each of the sections dealing with the different themes is structured to support effective decision-making, as described below. This structuring framework is outlined in Figure D.8.

Universal considerations

General aspects that should be taken into consideration when making higher level decisions regarding the theme of the particular section (as listed in Section D.3.1 above) 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 theme of the particular section 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 theme of the particular section that are available for consideration

Design considerations

Guidelines to assist with the design of the options that have been selected.

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 the particular section.

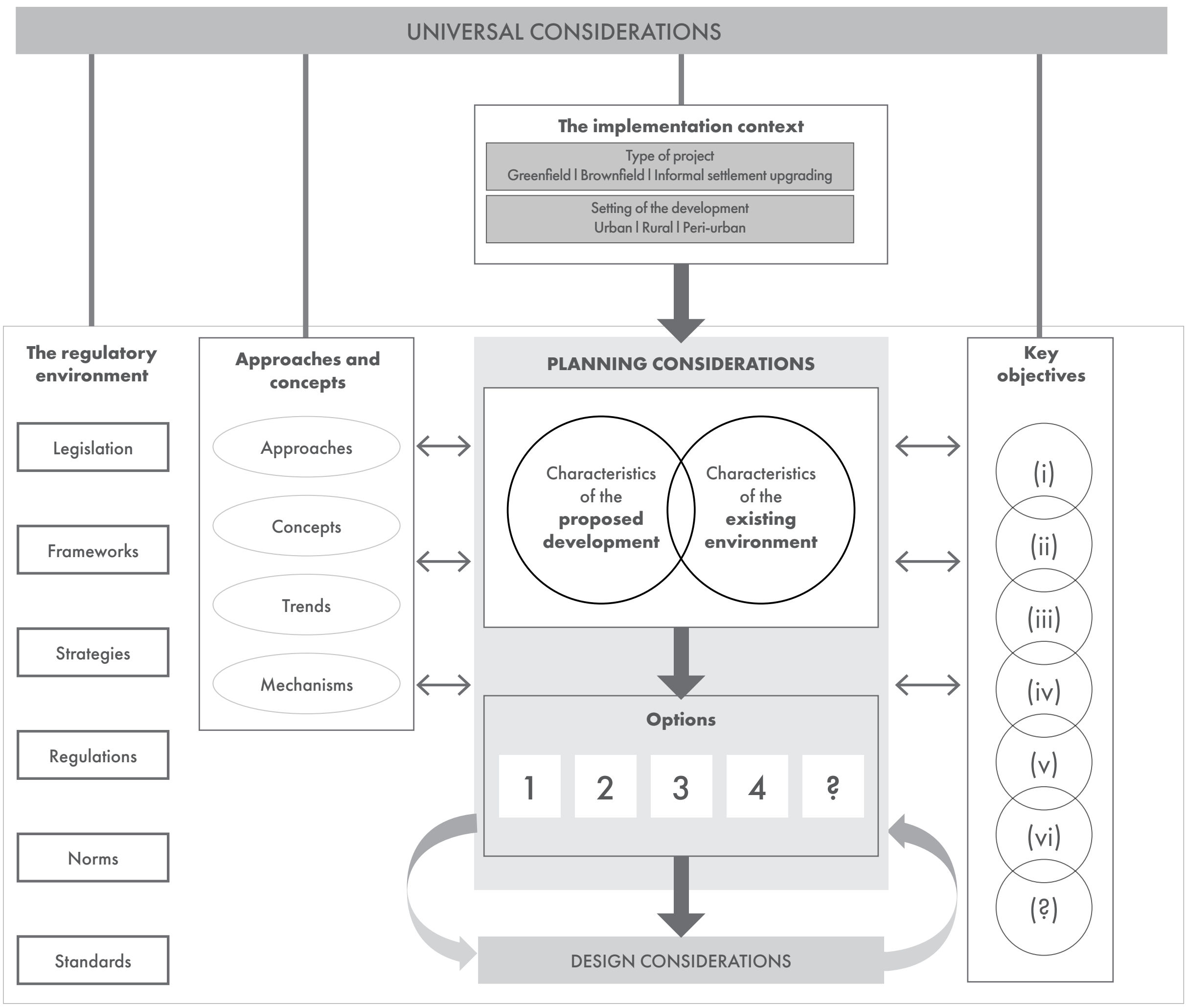

Figure D.8: A framework to assist with planning and design decisions

D.3.2 Options and choices

A range of service and infrastructure options are provided in each of the sections dealing with the various themes as listed in Section D.3.1. When applying this Guide, it is essential to consider as many factors as possible to assist in selecting the option most suitable to the development project being implemented. By using the framework presented in Figure D.8, useful information will be gathered to inform decisions regarding options. Decisions can be influenced by various factors, including financial considerations (capital and life-cycle costs), the context (location and associated characteristics) and user preferences. After all the factors have been considered, it may be necessary to make some compromises when deciding on the level and type of services and the infrastructure to be provided, since it may not always be possible to satisfy all requirements with one particular option.

When implementing projects that utilise government funding (grants and subsidies), in particular informal settlement upgrading projects, making these difficult decisions requires effective community participation (see Section E.1). This Guide provides those involved in such projects with information to assist in making informed decisions. The information also helps when trade-offs needs to be made when deciding between different levels or types of service, or when comparing different infrastructure options.

Section E
Working together

The Neighbourhood Planning and Design Guide

E.1 Participatory human settlement development

Very often, the success of a development project is dependent on the degree to which all role players actively participated in the implementation process. However, those responsible for implementing a development project (specifically a housing project in a low-income community) do not always have a clear understanding of the process that needs to be followed to involve the community and other key stakeholders, and they do not always see the benefit of doing this. Also, built environment professionals and technical consultants do not always have the capacity and skills to effectively engage with communities.

E.1.1 Participation versus consultation

A common misconception is that the involvement of the community and other key stakeholders is simply a step in the implementation process. Often it is seen as an event, or a few workshops that need to be held to satisfy certain requirements before moving on to the next step in the process. However, it should be an integral part of the entire process and the fundamental approach that governs all aspects, from inception through to implementation. Participation involves much more than consultation or information-sharing sessions. Participation, as opposed to consultation, allows for the active involvement of communities and key stakeholders in the decision-making process, rather than requiring them to (for instance) simply choose a type of technology or house from a set of pre-determined options presented.

There is a difference between community participation and consultation. When implementing a project, a consultative process often merely involves asking key stakeholders for their opinions about proposed interventions. This does not allow for meaningful involvement in the decision-making process. A participatory process, on the other hand, requires people to be actively involved in decision-making from the very beginning of a project that would affect them. They should participate in the planning, design implementation and management aspects, rather than only being involved after most of the critical decisions have been made.

Community participation means that all stakeholders are equal and active partners in the decision-making process, and it provides everyone with the opportunity to contribute, exposes them to challenges faced, and lets them share the responsibility of developing practical responses to deal with these challenges. A participatory process could assist in changing perceptions, empowering people and developing a common understanding.

A participatory process could be complex and time intensive. It is often worth it to include specialists in the field of community participation in the project team. Since the process should be as inclusive as possible, it is important to identify and involve all key stakeholders and the recognised leaders in the community. Stakeholders could include municipal councillors, faith-based organisations, schools, businesses, civic organisations, sport groups, residents' associations, informal trading organisations and other community-based organisations.

E.1.2 Co-production

For this Guide to make a tangible, positive difference in practice, an implementation approach is encouraged that is based on equal partnerships between a range of role players – from those involved in the planning, design and delivery of services and infrastructure, to those utilising these services and infrastructure. Such an approach, which requires citizens to be involved in all aspects of the delivery of services and infrastructure (including the conception, planning, design, delivery and management phases) rather than mere passive recipients, is often referred to as co-production.

The concept of co-production can be described in various ways. Essentially it means that those providing a service, and the citizens who make use of the service, all have contributions to make. The process is based on the notion that those who make use of a service are often in the best position to assist with the development of the most appropriate service.

Co-production descriptions

"Co-production means delivering public services in an equal and reciprocal relationship between professionals, people using services, their families and their neighbours. Where activities are co-produced in this way, both services and neighbourhoods become far more effective agents of change."[43]

"Co-production of public services means the public sector and citizens making better use of each other's assets and resources to achieve better outcomes and improved efficiency."[44]

"Co-production enables citizens and professionals to share power and work together in equal partnership, to create opportunities for people to access support when they need it and to contribute to social change."[45]

Photo credit: Community Organisation Resource Centre (CORC)

Figure E.1: Community members participating in the decision-making process

E.2 Inter-disciplinary collaboration

The range of disciplines involved in a development project need to work closely together in a coordinated way to achieve the objectives of this Guide. From the outset, built environment professionals need to cooperate on an ongoing basis to ensure that the planning and design process continues as effectively and efficiently as possible. Engineers, planners, architects and other built environment professionals involved in the planning and design process need to continuously communicate to ensure that the decisions made are not in conflict with each other.

Communication and coordination between the different disciplines is essential within both the municipal and the professional consulting team. From the outset, decisions made by the various professions need to take into consideration all aspects of the development and not only those that they are traditionally responsible for. For instance, decisions regarding the layout of a new development should be taken after considering the potential consequences they may have for the provision of engineering services and vice versa.

"The key to successful interdisciplinary collaboration is in understanding that it is not a technology but rather a psychology. Collaboration is not a process that can be codified into a set system; it is more of an attitude that needs to be inculcated in the culture of a firm.

It begins with every participant acknowledging that each of the others brings something valuable to the project and that their combined intelligence is more likely to deliver positive results than working in isolated silos."[46]

Glossary, acronyms, abbreviations

Glossary

Engineering services
Engineering services include water provision, sewage removal, stormwater disposal, solid waste removal, ICT and electricity supply.

Integrated Development Plan
An Integrated Development Plan (IDP) is a strategic plan that sets out the development vision for a municipality and guides and informs all planning, budgeting and decision-making related to service delivery and development in the municipal area. The core components of an IDP are described in Chapter 5 of the Local Government Municipal Systems Act (No. 32 of 2000).

Spatial Development Framework
SPLUMA requires all three spheres of government to produce Spatial Development Frameworks (SDFs). The focus of the three types of SDF differ. The national SDF provides broad strategic direction, provincial SDFs focus on the coordination of spatial development, and a municipal SDF contains detailed plans for the particular area of jurisdiction. Within the municipal sphere, the SDF forms a core component of the Integrated Development Plan (IDP) and guides the overall spatial distribution of current and desirable land uses within a municipality to give effect to the vision, goals and objectives of the municipal IDP. A detailed description of the content of SDFs is provided in Chapter 4 of SPLUMA.

Acronyms and abbreviations

ARP	Alexandra Renewal Project
BEPP	Built Environment Performance Plan
BNG	Breaking New Ground
CBD	Central Business District
GHG	Global Greenhouse Gas
IDP	Integrated Development Plan
IUDF	Integrated Urban Development Framework
NUSP	National Upgrading Support Programme
RDP	Reconstruction and Development Programme
SDF	Spatial Development Framework
UISP	Upgrading of Informal Settlements Programme

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Section F

Neighbourhood layout and structure

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 F

Neighbourhood layout and structure

The Neighbourhood Planning and Design Guide

Table of contents

F.1 Outline of this section

F.1.1 Purpose

Settlements (and neighbourhoods as the 'building blocks' of settlements) are integrated systems in which the various components are interconnected, and this section highlights the role of neighbourhood layout and structure in this system. The aspects addressed here play an essential role in achieving the vision for human settlements outlined in **Section B**, since the layout and structure of a neighbourhood could significantly affect the quality of the living environments created. The interrelationship between the different components of a neighbourhood such as open spaces, social facilities, housing and transportation, and their integration into the broader settlement, play an important part in responding to international imperatives (outlined in **Section B.1**) and South African policies (**Section B.2**). Certain objectives of this Guide (outlined in **Section C.1**) receive explicit attention in this section. In particular, the qualities that should be sought in settlements are clearly indicated, integrated planning and design are encouraged, and sound urban planning and design principles are promoted.

Some of the components of a neighbourhood referred to in this section are discussed in more detail in separate sections, namely public open space (**Section G**), housing and social facilities (**Section H**) and transportation (**Section I**). The services and infrastructure discussed in the other sections in Part II are all linked to the layout and structure of a neighbourhood and should also be carefully considered when applying the guidelines provided here. Special attention should furthermore be given to the guidelines related to crime prevention through environmental design (see **Section O.1**).

F.1.2 Content and structure

This section (Section F) is structured to support effective decision-making related to the layout and structure of a neighbourhood. The decision-making framework is outlined in Figure F.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 layout and structure of a neighbourhood 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 layout and structure of a neighbourhood 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 layout and structure of a neighbourhood that are available for consideration

Design considerations

Guidelines to assist with the design of the layout and structure of a neighbourhood.

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 F.

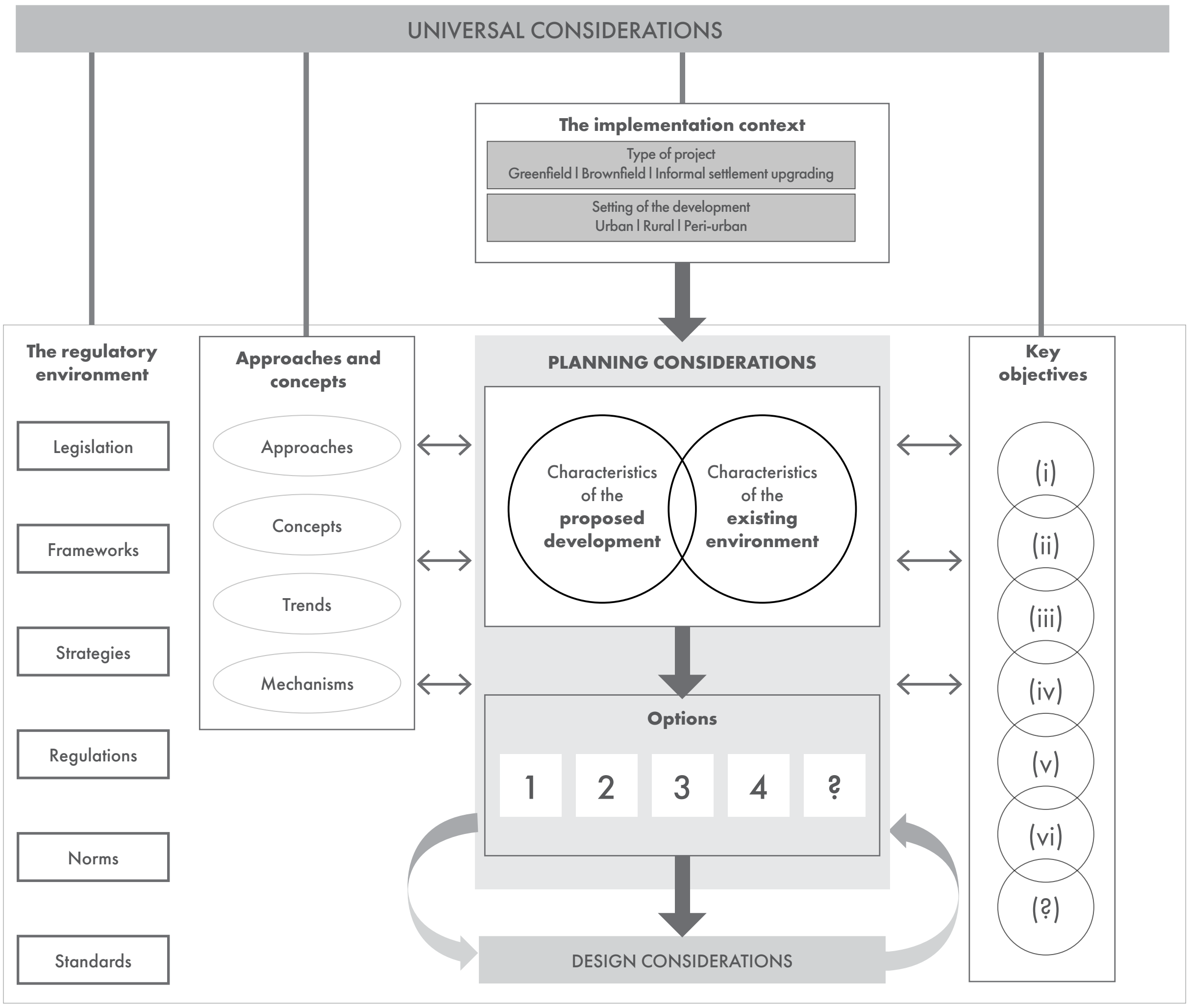


Figure F.1: A framework to assist with planning and design decisions

F.2 Universal considerations

F.2.1 The regulatory environment

A range of legislation, policies and strategies guide the development of settlements in South Africa. Legislation and policy that have direct implications for neighbourhood planning and design are briefly outlined 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.)

(i) The Spatial Planning and Land Use Management Act, 2013

The Spatial Planning and Land Use Management Act (SPLUMA) is a framework act for all spatial planning and land use management legislation in South Africa. Among others, SPLUMA requires that national, provincial and municipal Spatial Development Frameworks (SDFs) be developed. Development principles, norms and standards as identified in SPLUMA guide all actions relating to spatial planning and the development or use of land, and each municipality has to adopt and approve a single land use scheme for its entire area.

Certain aspects addressed in SPLUMA relate directly to neighbourhood layout and structure. Take note of the following requirements:

- Consider the municipal SDF when planning a project to ensure alignment with the SDF.
- Consider the municipal SDF when planning a project to understand the context of the project as depicted in the municipal SDF. Typical questions to ask include: What land use and densities are planned in the vicinity of the project? How will the project relate to the proposed developments in the rest of the municipal area?
- Adhere to the development principles (outlined in SPLUMA), namely spatial justice, spatial sustainability, efficiency, spatial resilience and good administration.
- Observe the regulations contained in the municipality's land use scheme regarding the use and development of land; the use, size and scale of buildings; and the intensity or density of land use.
- Adhere to the conditions of title as set out in the title deed of each property.
- If required, apply to the municipal planning tribunal to change the use, form or function of land, or to remove, amend or suspend a restrictive condition.

(ii) National Environmental Management Act, 1998 (and its subsequent amendments)

The National Environmental Management Act (NEMA) 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 its 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. A distinction is made between Listing Notices 1 and 3 activities, which require a Basic Assessment, and Listing Notice 2 activities, which require a full EIA (scoping followed by impact assessment). The latter involves a systematic and comprehensive process through which detailed information is gathered on the social, economic and environmental consequences of proposed developments. The environmental authority uses this information to decide whether development applications will be approved. NEMA also introduced the development of Environmental Management Plans, which most municipalities are considering or requiring when compiling SDFs. Other acts that support environmental management at a national level include the following:

- National Environmental Management: Protected Areas Act, 2003
- National Environmental Management: Air Quality Act, 2004
- National Environmental Management: Biodiversity Act, 2004
- National Environmental Management: Integrated Coastal Management Act, 2008

Certain aspects addressed in NEMA relate directly to neighbourhood layout and structure. Take note of the following:

- Apply the principles underpinning environmental management contained in the NEMA to all neighbourhood planning and design.
- Consult the national register of all national, provincial and local protected areas to determine their proximity to and possible impact on the project site.
- Determine the nature of the activity proposed in a development project and consult with the local municipality to determine what kind of assessment is required for the site.

(iii) National Heritage Resources Act, 1999

The National Heritage Resources Act introduces an integrated and interactive system for the management of national heritage resources. According to the act, heritage sites, protected areas and heritage areas need to be taken into consideration when developments are planned (see **Section F.3.2.1. (v)**).

(iv) International, national, provincial and local policies, frameworks and guideline documents

Neighbourhood planning and design should be influenced and informed by the Sustainable Development Goals (SDGs) adopted by the UN Assembly in 2015. Goal 11: 'Making cities and human settlements inclusive, safe, resilient and sustainable' applies directly to settlement planning and design. The New Urban Agenda adopted in 2016 at Habitat III should guide efforts around planning for urbanisation. At continental level, the African Union's Agenda 2063 and its strategic goals should be considered (refer to **Section B.1**).

At national level, the National Development Plan 2013 calls for improved spatial efficiency and inclusion, while the Integrated Urban Development Framework (IUDF) 2016 is the South African government's policy position to guide the future growth of urban areas. Spatial targeting proposals are contained in a range of policy documents, including the Comprehensive Rural Development Programme, the Provincial Growth and Development Strategies (PGDS) and other regional plans and policies (refer to **Section B.2** for a discussion on the national policy environment).

At a local level, the planning mechanisms employed by municipalities need to be considered, including long-term development visions and city development strategies, all Integrated Development Plan (IDP) sector plans, as well as the SDF and Built Environment Performance Plans (BEPPs). Several national government departments have introduced guidelines aimed at the local level, such as the Department of Rural Development and Land Reform's guidelines on open space and the National Treasury's Urban Network Strategy toolkit. In addition, municipalities often have their own guidelines on aspects such as urban design, open spaces, public facility provision and the support for informal and small businesses in well-located spaces.

It is important to take into consideration all goals, principles, spatial implications and guidelines contained in these documents when planning and designing the layout and structure of a development.

F.2.2 Key objectives

Positively performing neighbourhoods – those that are generally regarded as successful and liveable – tend to have certain characteristics in common. Successful neighbourhoods do not always exhibit all these common characteristics, but they often tend to be integrated and connected, inclusive, convenient, resilient and adaptable, efficient, safe and healthy, economically supportive, and characterful and aesthetically pleasing.

These characteristics could be translated into a set of objectives that should guide the planning and design of a development. The following objectives should always be considered when decisions are made regarding the layout and structure of a neighbourhood development:

- Integration and connectivity
- Inclusivity
- Convenience
- Resilience and adaptability
- Efficiency
- Safety and health
- Economic opportunities
- Aesthetics and character

Harmony between the natural and built environments

While the development of a neighbourhood should be guided by the objectives as summarised in Figure F.2, it is also essential to maintain a harmonious relationship between the natural and built environments.

A healthy, functioning ecosystem is a vital aspect of settlements and neighbourhoods. The built environment inevitably affects the natural environment, and it is critical to ensure that it does not have an adverse effect on the ecology. Developments could have various negative consequences, including the loss of habitat, the destruction of wetlands with their associated vegetation, the removal of vegetation, subsoil and topsoil containing material essential to the local fauna and flora.

The importance of ecological systems should always be acknowledged when planning and designing the layout and structure of a neighbourhood, and the local ecosystem should as far as possible be incorporated into the development. Du Plessis and Brandon[1] take it a step further and promote an approach where the aim should be to reintegrate human habits and habitats with nature, merging and working with nature to produce a net positive impact rather than merely reducing negative impacts.

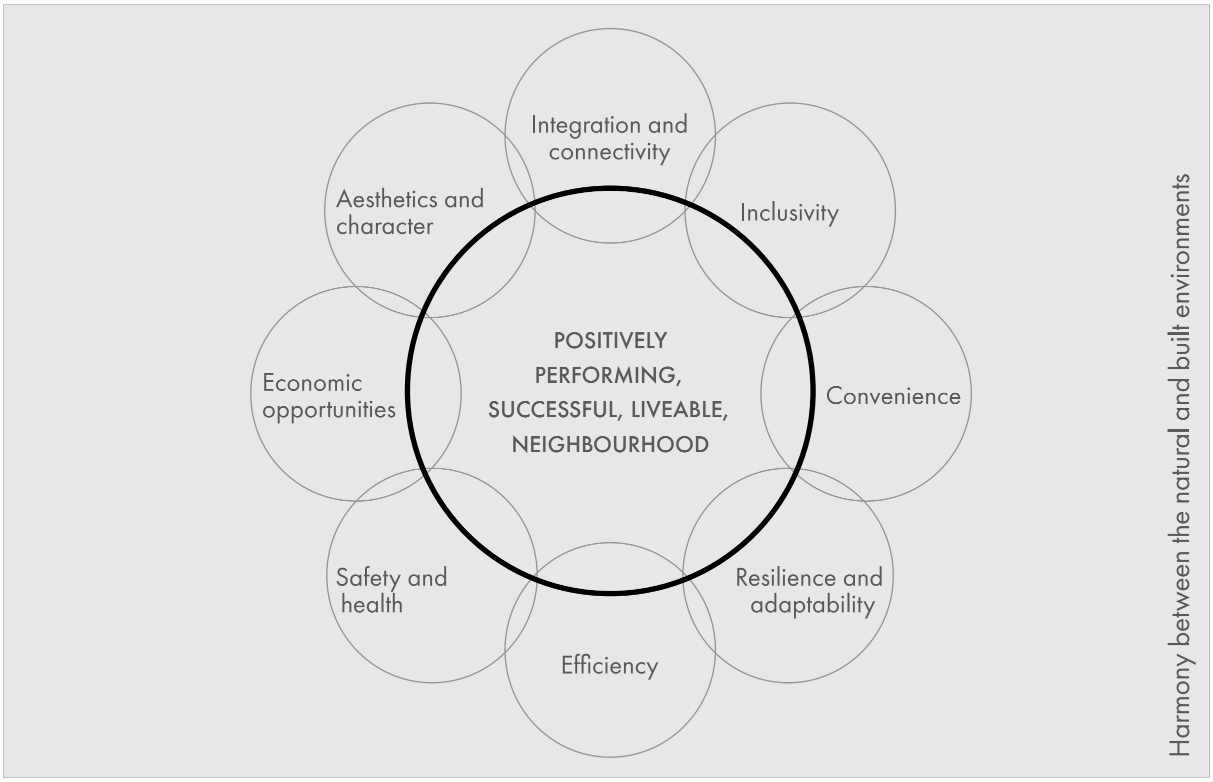


Figure F.2: Key objectives - creating positively performing neighbourhoods

(i) Integration and connectivity

Neighbourhoods are the 'building blocks' of a human settlement. Each neighbourhood plays a particular role in the settlement, and together the different neighbourhoods define the form and character of a city or town. Ideally, neighbourhoods should complement each other and 'fit' together in order to benefit from and contribute to a much larger area. Stand-alone, inward-oriented neighbourhoods that rely largely on their own internally generated resources result in a spatially, socially and economically fragmented settlement.

The layout and structure of a new development should contribute to assimilating the development into the surrounding neighbourhoods. By integrating a new development into the broader area, it can make a positive contribution to the city or town, while potentially allowing access to economic opportunities and public services and facilities.

> The layout and structure of a neighbourhood could connect that neighbourhood to other parts of a settlement by means of, for instance, well-designed transportation networks and open-space systems, and a range of appropriately located social facilities.

(ii) Inclusivity

An inclusive neighbourhood values all people, embraces diversity and acknowledges the contributions and needs of all. It means that everyone is accommodated, and their particular needs and circumstances are taken into consideration as far as possible. Often this involves catering for specific cultural, religious and traditional requirements, or making provision for supporting homeless and indigent residents.

Inclusivity also means that residents are presented with options from which to choose. Neighbourhoods should be multifaceted, offering a diversity (and thus choice) of places, lifestyles and activities. They should also provide opportunities for human contact and interaction, allowing people to live on their own but not be alone.

Neighbourhoods should also provide people with choices regarding the extent to which they wish to engage in social activity. Some people require places that are private and that allow them to distinguish between the 'locals' and the 'strangers'. Some people wish to live in intensive and vibrant environments, others in quieter and more private places. These requirements vary from person to person and over the life-cycle of households. Hierarchies of movement, public spaces and social facilities, as well as the design of living areas can influence relative degrees of privacy or exposure.

Inclusivity furthermore relates to universal access, which refers to environments that aim to accommodate all users regardless of their age, gender, ability or specific circumstances. An inclusive environment is a user-friendly environment that does not have barriers that would prevent certain people from using it, including those who may have difficulties moving, hearing, seeing or communicating.

The layout and structure of a neighbourhood should encourage and facilitate inclusivity by, for instance

- allowing all residents to participate in their daily activities, including specific cultural, religious and traditional requirements,
- making provision for supporting homeless and indigent residents,
- creating an environment that accommodates all and allows residents to move around with relative ease by applying universal (inclusive) design principles, and
- promoting environments that provide a range of options, so that people do not have 'either/or' choices, but rather choices between options that they feel comfortable with.

(iii) Convenience

Neighbourhoods that are convenient allow residents to conduct daily activities efficiently, that is with ease and without undue delays. This means that services, retail facilities and public amenities, for instance, should be easily accessible. Access lies at the heart of convenience and is one of the main factors that influence the location, growth and functions of neighbourhoods. Convenience is improved when it is easy to get to and from a neighbourhood, and when it is easy to move around in a neighbourhood, especially on foot.

For those residents who cannot afford a motor vehicle, public transport is crucial to facilitate movement. Although this does not deny the need to accommodate motor vehicles in settlements, the structuring of settlements, particularly for those who cannot afford private transport, should encourage and facilitate pedestrian movement and public transport systems.

Access to nature is important to many people. For financial reasons, contact with nature sometimes has to be collective contact as it cannot always be provided adequately within private gardens. In addition, the productive capacity of the land can be a vital settlement resource. For many settlement dwellers, the opportunity to use the land productively or to engage in lifestyles that incorporate dimensions of both urban and rural living, is crucial to their survival.

The layout and structure of a new development could contribute to creating a convenient environment in a number of ways, for instance by

- providing an interconnected network of streets that provide people with a choice of routes that are safe, efficient and pleasant to use whether they are walking, cycling or driving,
- creating permeable neighbourhoods by providing frequent connections between existing and new streets and pathways, and
- linking social facilities with movement systems, so that people can walk, cycle and use different transport modes to access economic opportunities, community, education and healthcare facilities, commercial and entertainment areas, open spaces, places of recreation, etc.

(iv) Resilience and adaptability

Human settlements are constantly exposed to a range of threats, including floods, storms, fires, droughts and earthquakes. Such extreme weather conditions often cause sudden, devastating disasters, and due to climate change these conditions will become more and more common. In addition, settlements could also experience chronic stresses caused by longer-term disasters, including extreme levels of crime and violence, poverty and inequality. Settlements need to be prepared for these disasters and be able to withstand the consequences. This ability to survive different stresses and shocks, to adapt to the changing conditions and to recover from such catastrophic disruptions is referred to as resilience.

Neighbourhoods are subject to change over time. Because it is better to anticipate change rather than merely respond to it, the ways in which a neighbourhood may be required to change should be anticipated and planned. Possible changes that have to be considered include economic and societal changes, as well as changes in the environment, the needs of the residents and the composition and use of the neighbourhood.

The layout and structure of a new development should enhance the neighbourhood's capacity to adapt to change. It should also contribute to the creation of resilient settlements, for instance through the provision of essential services and facilities, dependable, robust and well maintained infrastructure, and reliable movement networks.

(v) Efficiency

The development of neighbourhoods requires the use of a wide range of resources including land, money, building materials and human capital. Development also makes use of, or has an impact on, natural resources such as air, energy and water. Neighbourhoods should be planned and designed to use these resources efficiently.

The layout and structure of a neighbourhood could improve resource efficiency by, for instance, applying the principles of water sensitive urban design and sustainable drainage systems, encouraging walking and the use of non-motorised transport, and considering long-term maintenance and life-cycle costing during planning and design.

(vi) Safety and health

In a safe and healthy neighbourhood there is a strong emphasis on reducing actual and perceived levels of crime and violence and a focus on injury prevention. In such a neighbourhood, environmental health risks are minimised, the physical and mental wellbeing of all residents is supported, and safe conditions are created for all street users, especially pedestrians and cyclists.

The layout and structure of a new development could contribute to the creation of safe and healthy neighbourhoods by, for instance

- reducing opportunities for criminal activities, especially in public spaces, for instance through the use of the principles of crime prevention through environmental design (refer to Section O.1),
- providing opportunities for residents to improve their physical and mental health, for instance by creating an environment that encourages walking and the use of non-motorised modes of transport,
- reducing exposure to environmental health risks and the risks of injury, and
- creating safe conditions on streets and sidewalks.

(vii) Economic opportunities

People often come to settlements to improve their personal welfare. This welfare has many dimensions. People may move into neighbourhoods to find shelter and also to make use of other opportunities offered by the concentration of people and the frequent human interaction. A significant proportion of workers in urban settlements are informal workers. These workers sell food or other household items, drive taxis, perform hard labour and gather, sort and recycle what industry and households throw away. In these and other ways, they earn livelihoods that sustain entire families.

Neighbourhoods should generate economic opportunities, and their layout and structure should contribute by supporting local, particularly small-scale, economic activity (employment, production and consumption), enabling efficient transportation and movement systems, and facilitating higher densities.

(viii) Aesthetics and character

Settlements are about people and places and how they interact. Residents spend a great deal of time in their individual neighbourhoods and often identify more strongly with the neighbourhood than with the settlement as a whole. An attractive, aesthetically pleasing physical environment could add to the quality of the neighbourhood. A characterful neighbourhood is more pleasant and interesting for residents and visitors, and gives it a unique identity. The way streets are laid out and public spaces are juxtaposed with adjoining buildings can play an important role in the creation of well-functioning, visually appealing neighbourhoods.

Neighbourhoods with good aesthetic qualities and a pleasant character contribute to people feeling comfortable and safe. It is essential to consider the following when making decisions regarding the layout and structure of a development:

- Acknowledge the local context and identify features that could be incorporated into a development to create a distinct character or identity.
- Recognise traditional, cultural or religious views and customs, and sensitively incorporate places of significance, natural and cultural assets, and heritage sites into a development where appropriate.
- Enhance the legibility of an area by helping people to orientate themselves, for instance through the use of a street network that is easy to understand and the incorporation of structuring elements such as landmarks, vistas and other distinct natural or built environment features. A neighbourhood is legible if the layout pattern is clear and simple and enables residents and visitors to understand how the different parts of the neighbourhood is organised, allowing them to easily make their way around.
- Pay special attention to the interaction between open space and the buildings shaping these spaces, and recognise what can be achieved through creative architecture and the innovative use of building materials, paving, landscaping and so forth to create distinctive, attractive and vibrant outdoor areas with a sense of place.

F.2.3 Approaches and concepts

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

F.2.3.1 Transport-oriented development

Transport-oriented Development (TOD) refers to the concentration of a mix of medium to high-density, NMT-friendly developments around a public transport station or interchange or along a transport or activity corridor. From a transport perspective, the intention is to improve access to public transport, reduce travel time and promote the use of NMT to ultimately reduce the reliance on private cars.[2] From a spatial development perspective, the focus would be on higher densities and providing adequate public spaces and a mix of land uses (residential, employment, leisure and retail) within the same space.[3] The key features of any TOD generally include mixed land use, increased residential density, social (and housing) mix, high-quality pedestrian environments and good access to services and employment. It is important to keep in mind that TOD is site specific and dependent on the proximity and nature of public transport stops and stations.

The potential of TOD to drive the restructuring of South African settlements has been identified in many government plans and strategies, specifically the NDP and the IUDF. The National Treasury's Neighbourhood Development Programme has done extensive work in applying the principles of TOD to South African cities through its Urban Networks Strategy that targets investment in identified 'urban hubs'. Relevant documents and guidelines are available from the Neighbourhood Development Programme.[4]

F.2.3.2 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] 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 F.3.)

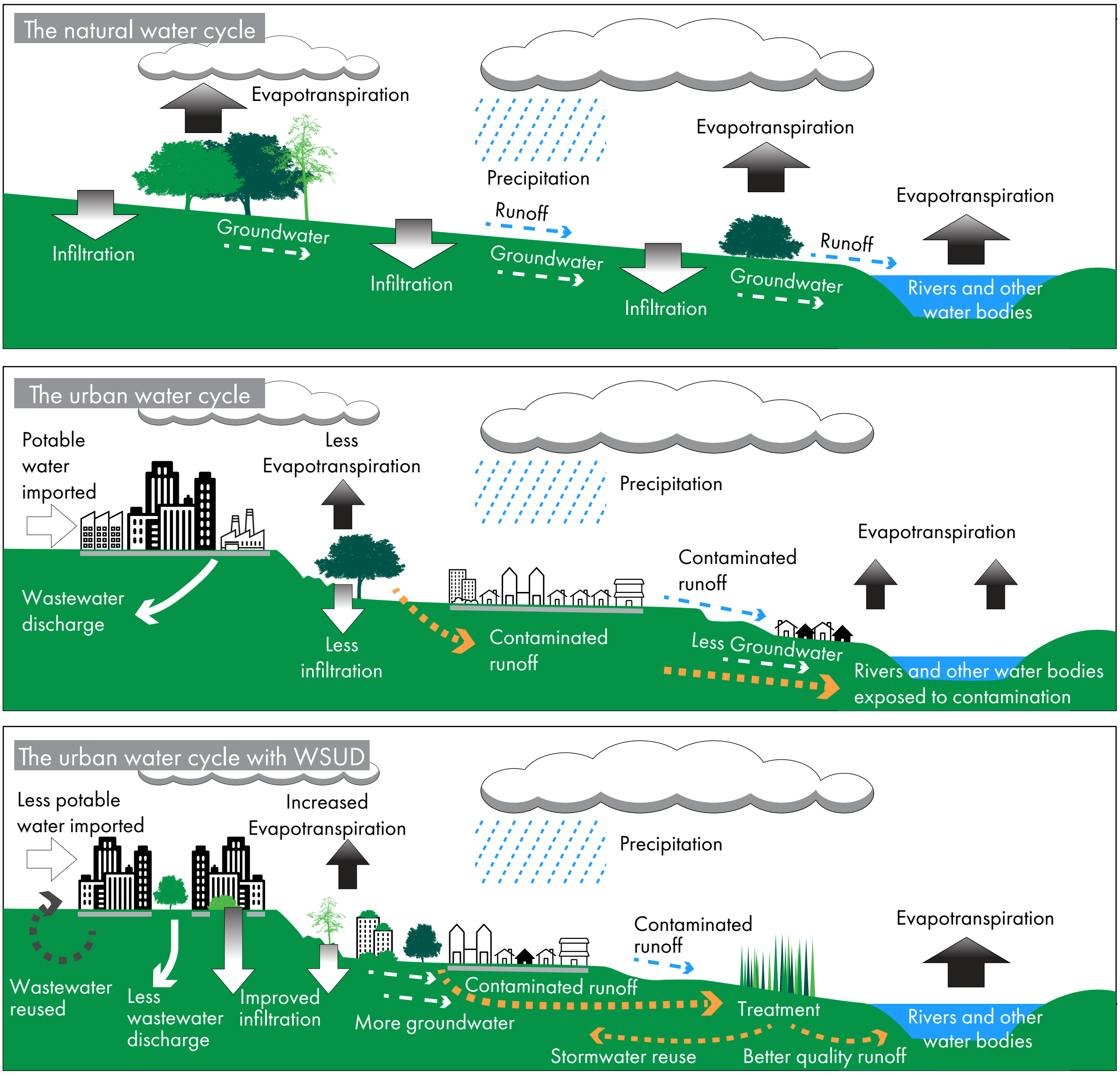


Figure F.3: The water cycle under different conditions

The natural process (water cycle) involves, amongst 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 water 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 J** (Water supply), **Section K** (Sanitation), and **Section L** (Stormwater).

F.2.3.3 Multi-modalism

Multi-modalism promotes the provision of a network of transport options for people to choose from, including not travelling at all. It presents a move away from private vehicle dependency and prioritises giving people choice. The quality and liveability of neighbourhoods are enhanced when residents have choices. Multi-modalism allows more mobility, while decreasing the transport cost burden, which includes roadway costs, parking costs, consumer costs and costs related to congestion, traffic accidents, energy consumption and pollution emissions. When planning and designing the layout and structure of neighbourhoods, it is important to do the following:

- Improve the connectivity of the transport system by focusing on the connections between modes, such as the quality of pedestrian and cycling access to public transport stops and stations
- Incorporate universal design and consider affordability to ensure that mobility options are available to all people

F.2.3.4 Compact cities

The concept of compact cities promotes neighbourhoods with high residential densities, mixed land uses and clear boundaries. The land uses are typically supported by public transport and by measures to encourage walking and cycling, which results in the reduction of energy consumption and pollution. The idea behind this model of planning and design is to move away from unsustainable urban sprawl that increases infrastructure cost and private motor vehicle dependency. The compact cities concept has strong associations with a number of other concepts, including intensification, urban containment, growth management and smart growth. Issues to consider include mixed land uses, compact building design, housing opportunities and choices, walkable neighbourhoods, transport options and choices and strengthening existing communities.

Concepts associated with compact cities (from the *Journal of Planning Education and Research*[9])

- **Intensification** is the process of using land more efficiently by increasing the density of development and activity. Intensification includes the development of previously undeveloped urban land, the redevelopment of existing buildings or previously developed sites, as well as subdivision, conversions, additions and extensions.
- **Urban containment** involves measures to prevent the outward expansion of settlements and typically includes introducing 'push' and 'pull' factors to manipulate new development in order to achieve a particular settlement form. An example would be the introduction of an urban growth boundary. This concept overlaps to a large extent with the concept of growth management.
- **Smart growth** promotes similar measures to manage settlement growth, but it deliberately attempts to balance growth with the meeting of economic, social and environmental needs.

F.2.3.5 Eco-cities

The eco-city is an umbrella concept that includes a wide range of urban-ecological proposals that aim to achieve urban sustainability. The eco-city is often modelled on the self-sustaining resilient structure and function of natural ecosystems. The aim is for inhabitants not to consume more (renewable) resources than the city produces, without producing more waste than it can assimilate, and without being toxic to itself or neighbouring ecosystems. The core of many of the approaches included under the eco-city umbrella is the management of the city, rather than suggesting a specific settlement form. However, the distinctive physical planning and design concepts that are promoted to realise the eco-city include greening, green infrastructure and passive solar design.[10]

F.2.3.6 Smart cities

The digitalisation of cities appears to be inevitable and the strategic use of Information and Communications Technology (ICT) can potentially assist, even in low-resource or low-income settlements, in the planning and design of positively performing neighbourhoods – those that are regarded as successful and liveable (see Section F.2.2).

There is no universally accepted definition of a smart city. At the moment, digital interventions towards the smart city tend to focus on better and new ways of data collection and interpretation and on connecting people and objects with each other. The data collected is analysed to support decision-making, manage resources efficiently and improve the effectiveness of different urban elements or processes. This might include aspects such as e-governance and other citizen services, smart water metering, water quality monitoring and leak detection, smart parking and intelligent traffic management, energy efficient buildings and maintenance management with the help of censors. The Internet of Things (IoT) is an umbrella term referring to the drive to equip different objects with sensors that enable them to communicate and to share data with people (users) and other objects. Improved connections between people also have multiple implications for the planning and design of human settlements.

F.2.4 The implementation context

This section highlights the contextual factors that should be considered when planning and designing the layout and structure of a neighbourhood, specifically related to the type of development and its setting. Also refer to **Section D.2.1** (Type of development) and **Section D.2.2** (The setting of the planned development).

F.2.4.1 The type of development

(i) Greenfield development

When planning and designing the layout and structure of a neighbourhood as part of a greenfield development project, the following must be considered:

- Undisturbed portions of the natural environment are often found on greenfield sites. The preservation of open space, trees and on-site natural features should be considered when planning and designing the layout and structure of a neighbourhood. This could provide a unique and appealing amenity for future users.
- Greenfield sites often are not connected to municipal services such as water, sanitation, stormwater, electricity and solid waste removal. These service connections may even be a substantial distance away, especially if the site is in a rural area. The capacity of the services may also not be sufficient for the proposed development and an upgrade may be required to adequately service the proposed development. 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 neighbourhood layout and structure.
- Depending on where the greenfield site is located, it might be a challenge to connect to existing public transport routes. Access points are very important for the viability of a new neighbourhood and will therefore be a determining factor that could influence the layout and structure.

(ii) Brownfield development

When planning and designing the layout and structure of a neighbourhood as part of a brownfield development project, the following must be considered:

- Site assembly is often essential as part of a brownfield development. This involves combining small plots and individual properties with multiple ownership arrangements into larger parcels for comprehensive redevelopment. Site assembly is an intricate process and the outcome can have an impact on the layout and structure of a new neighbourhood.
- Brownfield sites are potentially contaminated by previous industrial uses or leftover building materials and might need environmental rehabilitation. If rehabilitation is not possible or appropriate, the contaminated land may have an impact on the layout and structure of the neighbourhood, as residential land uses and/or conventional construction methods may not be possible on certain parts of the site.

- Sites for redevelopment are often located in inner city areas and are associated with very specific issues such as traffic congestion and noise that must to be taken into account when planning and designing neighbourhood layout.
- The layout and structure of the brownfield development project should link up with existing movement patterns and surrounding streets to provide as many access points into the site as possible.
- The layout and structure should also respond to the local context in terms of the landscape, the built form and the land use pattern.
- Sites for redevelopment often have built structures that may have heritage value. Preserving the unique heritage elements on site can enhance existing and potential place-making elements and localities to create a unique place-structure that responds to the urban and natural context.
- Brownfield projects often result in higher population densities. When planning and designing the structure and layout of the neighbourhood, population density may have an impact on the planning and design of municipal engineering services, as the existing infrastructure may not have the capacity to cater for these higher densities.

(iii) Informal settlement upgrading

Informal settlement upgrading often involves in-situ development, which implies that existing houses are left in place while the neighbourhood is upgraded – streets are aligned and widened, drainage is improved, and homes are connected to the water and sanitation grids. When planning and designing the layout and structure of a neighbourhood as part of an informal settlement upgrading project, the following needs to be considered:

- Informal settlements are often isolated from the settlement street grid. Linking up with existing movement networks and surrounding streets will have a major impact on the neighbourhood layout and structure.
- Informal settlements grow organically and there may be layouts that seem unconventional. The internal layout and structure of the upgraded informal settlement have to accommodate these anomalies.
- As informal settlements are mostly associated with higher densities, there would be increased focus on creating pedestrian-friendly streets when designing the layout, including pathways, stairs and steps.
- When planning and designing the structure and layout of the neighbourhood, the higher population density may have an impact on the planning and design of municipal engineering services, as the infrastructure in adjacent neighbourhoods may not have the capacity to cater for these higher densities.
- Of critical importance when planning and designing the layout of an informal settlement upgrading project, is to involve the residents. Informal settlements are not homogenous; each has its own unique community characteristics and different levels of social cohesion.

F.2.4.2 The setting of the development

(i) Urban

The urban areas of South Africa comprise a variety of settlement types. When making decisions regarding the layout and structure of an urban development, the following should be considered:

- New developments can lead to urban sprawl. The negative effects of this phenomenon should be reduced as far as possible.
- South Africa's inner cities are changing. They are no longer the only commercial hub in many cities. Multiple commercial nodes across the city will have an impact on layout proposals as multiple linkages and access points should be provided.

- Informal settlements often require in-situ upgrading and the layout design process requires an approach that relies on intensive community participation.
- Ecosystems provide critical services to urban communities such as clean water, air, biodiversity and productive soils. Protecting ecosystems through layout planning and design builds the resilience of all communities.

(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 the layout and structure of 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 growth are concentrated in these zones of rural-urban transition.[11] The often-high rate of urbanisation (influx or people into cities) should be considered when planning and designing the layout and structure of new developments as there is a likelihood that peri-urban areas will have to accommodate more people and higher densities in future.
- Land on the periphery often does not have convenient access to urban amenities. When designing and planning the layout and structure of a development, it is important to link the development to key movement systems and specifically to existing public transport routes to allow for access to the rest of the settlement, in particular to established economic nodes.
- The boundary line between rural, peri-urban and urban is not well-defined and therefore tends to be adjusted often. Municipalities make use of a range of urban growth measures, of which the urban edge is one. When planning and designing the layout and structure of a project, it is critical to determine whether there is an official urban edge delineated, what its proximity is in relation to the development and how this will affect future change in the development.
- The costs of providing conventional urban infrastructure in peri-urban areas are often prohibitive. If alternative ways of service provision are considered, e.g. so-called package plants for sewer treatment, it could influence the layout and structure of a development.
- Ecosystems provide critical services to peri-urban communities such as clean water, air, biodiversity and productive soils. Protecting ecosystems through layout planning and design builds the resilience of all communities.
- Peri-urban areas are also often home to gated communities or security complexes. These developments are sometimes criticised for being enclaves that contribute to the fragmentation of urban form and for promoting the use of private motor vehicles. The internal layout and structure of these peri-urban settlements are often carefully planned to support walkability and provide residents with improved access. However, in most cases gated communities on the urban fringe do not respond to their immediate surroundings in terms of layout and structure.

(iii) Rural

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

- Most traditional villages are located on farm portions or on trust land. The trust land is communally owned and is usually managed by a hierarchy of traditional leaders. Neighbourhood layout and structure decisions are directed by these decision-makers rather than by the local municipality's SDF or land use scheme.

- In a rural residential area, activities such as the traditional slaughter of animals, home burials, or seasonal land uses have to be accommodated when planning neighbourhood layout and structure.[12]
- Rural communities may provide certain services themselves, and these may have to be accommodated in the layout of the development.
- Ecosystems provide critical services such as clean water, air, biodiversity and productive soils to rural communities. Protecting ecosystems through layout planning and design builds the resilience of rural communities.
- Many rural households are much less likely than urban households to have access to a supply of piped water close to their dwellings. Therefore, household activities often include the collection of water, and in such cases the layout and structure of a development need to be particularly pedestrian-friendly.
- Sometimes rural settlements can only be accessed by dirt roads or even footpaths. These roads are particularly vulnerable to degradation during rains.[13] In addition, the organic nature of the internal street layout of rural settlements makes it difficult to achieve certain efficiencies. The proper planning and design of street layout and neighbourhood structure should attempt to deal with some of these challenges.

The spatial form of rural settlements, specifically those under traditional leadership, differs throughout South Africa. According to the Department of Rural Development and Land Reform's *Land Use Scheme Guidelines*[14], in the provinces of North West and Limpopo, traditional villages are often arranged in square gardens and within square blocks, with livestock kept within the boundaries of each household, while houses and huts in KwaZulu-Natal are sometimes arranged on hilltops or on slopes or along river courses. Occasionally the houses are close together to form a village. These different spatial forms are largely associated with different cultures and traditions, as well as with the topography of the area. The planning and design of the layout and structure of a new project should respect and respond to the tradition and culture of the local people.

F.3 Planning considerations

This section deals with the planning of the layout of neighbourhood streets, the delineation of plots (private and public) and the allocation of different land uses. 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 layout and structuring options based on a thorough understanding of the context within which the planned development will be implemented.

The decisions regarding layout and structuring 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.

This section outlines a range of questions that should be asked and factors that have to be considered to inform decisions regarding neighbourhood layout and structure.

F.3.1 Characteristics of the proposed development

Decisions regarding neighbourhood layout and structure 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.

F.3.1.1 The nature of the proposed development

The nature of the development that is planned will influence the street layout, the size of the land units and the type of engineering and other services to be delivered. The following questions can be asked to gain clarity:

- What is the dominant land use of the proposed development?
- What supporting land uses will be required?
- What social facilities should be provided and planned for?
- 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)

F.3.1.2 The residents of the area to be developed

Decisions regarding neighbourhood layout and structure need to be guided by information about the potential residents and users of the planned facilities. Usually, the identities of the actual occupants of the houses to be provided are not known when a development is planned and designed. It may be possible to make assumptions regarding the expected nature of the future residents by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to establish the following:

- The total number of residents to be accommodated. Actual numbers may be higher than anticipated because the provision of houses and 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 which types of housing and services would have to be provided.
- The range of residents with special needs that would have to be accommodated, e.g. people living with HIV/Aids and with disabilities, including physical, dexterity and sensory impairment. Infrastructure and services should, as far as possible, be accessible to all residents and users.
- Age and gender of residents (i.e. gender ratios and age profile). An ageing population might, for example, require access to buildings at the ground level.
- Income and employment levels and spending patterns. This could, for instance, indicate to what extent housing should be able to accommodate private motor vehicles, and what types of streets and other infrastructure and services would be most appropriate.

F.3.2 Characteristics of the existing environment

Decisions regarding neighbourhood layout and structure 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.

F.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the site could influence the layout and structure of the neighbourhood.

(i) Topography

The topography of the project site is a key factor when making decisions regarding the layout of the development. The landscape will influence the micro-climate of the site and have a significant impact on the provision of municipal engineering services. Asking the following questions will assist in highlighting pertinent issues:

- Does the site slope? Are there significant changes in level such as embankments or retaining walls? A sloping site could mean that additional costs would have to be incurred when constructing streets, infrastructure and buildings. It may also be difficult to provide certain housing types on very steep sites.
- How will the slope or level changes affect the site layout and the positioning of buildings? Severe slopes or level changes may make it difficult to position houses and other buildings to face north, or it could be difficult to provide vehicle access to the site.
- Can the development be oriented to make the most of attractive views?

(ii) Climate

The micro- and macro-climates of the site will have an impact on street layout and plot orientation. The following questions need to be asked:

- Is the site exposed to prevailing winds? Is the wind direction seasonal? This information would assist in positioning a building on a plot.
- Where does the sun rise and set in summer and winter? The presence of shade may be important for the orientation of blocks and plots. Remember there may be external features that influence sun penetration on the site, such as a nearby mountain, hill, tree, or building.
- Does the site fall in a declared natural disaster zone? Is there a risk of seasonal flooding, earthquakes, tremors, veld fires and landslides? Do disaster management plans exist? For assistance with the development of actions to adapt settlements to the impacts of climate change, consult the *Green Book: Adapting South African settlements to climate change.*[15]

(iii) 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 might not be suitable for construction. The ground conditions could also have implications for the population density or housing density that can be accommodated on the particular site and will have an impact on decision-making regarding plot dimensions and street widths. The following questions might be helpful:

- What is the soil condition and quality?
- Are there any aggressive chemicals or minerals present?
- Is the site part of or close to a dolomitic area?
- Was the site used for mining and exploration in the past?
- Are there large rock outcrops on the site? Are there gullies or other ditches on the site?
- Is there groundwater present? What is the height of the water table?
- Did dumping – legal or illegal – ever occur on the site? It is difficult to stop people from using a dumping site that was established informally. Where possible, illegal dumping sites should be converted to legal dumping sites in the final layout of the neighbourhood.

(iv) Landscape and ecology

The physical features of the landscape could have a substantial impact on the neighbourhood layout and structure. A thorough analysis of the landscape and ecology should be conducted to determine if there are certain parts of the project site that would not be suitable for development. If the site is located in or near an ecologically sensitive area, there may be restrictions that could influence the positioning (and ease of construction) of infrastructure, streets, houses and other buildings. 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 or underground 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) and Ecological Support Areas (ESAs) is available on the website of the South African National Biodiversity Institute (SANBI)[16]
- Endangered or protected plant or animal 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

(v) Existing buildings on the site

If there are existing buildings on the proposed development site, they can be viewed as either presenting opportunities or constraints. Depending on the specific circumstances, existing buildings could restrict the layout options available, or they could add interesting alternatives and may even become structuring elements. To determine the most appropriate course of action, the following questions can be asked:

- Do the buildings have features of historic or conservation interest? (Refer to the text box on the following page for a discussion on heritage as part of neighbourhood planning and design.)
- Do the buildings have cultural significance? May these buildings be demolished?
- Should these buildings be refurbished? Can these buildings be repurposed and reused? Can these buildings be integrated into the new development?

Heritage conservation and neighbourhood development projects

Heritage resource conservation and management in South Africa is governed by the National Heritage Resources Act, 1999. The act provides for the conservation and management of heritage resources and empowers society to assist in this management.

The act is administered by the South African Heritage Resources Agency (SAHRA) at national level. There are also provincial heritage resources authorities, while some cities manage their heritage areas at a municipal level. Thus, heritage resources and heritage areas are protected by law at local, provincial and national levels. It is important to determine which authority is responsible for the area in which the new development is proposed. Under certain circumstances it may involve all three spheres of government.

Heritage resources include settlements, places, objects, buildings, cultural practices and traditions that are valued by communities and are therefore culturally significant. A heritage resource is recognised as being culturally significant when it has historical, aesthetic, scientific and/or social value. The resource may be a tangible object or place, or an intangible practice or tradition.

A heritage area, as defined in the National Heritage Resources Act, is a designated place of environmental or cultural interest. The designation will be made based on a combination of architectural, historic, aesthetic, scientific and social characteristics. Typically places, buildings and landscapes with symbolic significance will be included in the designation. If a new development is situated within a declared heritage area, or is adjacent to a declared heritage building, it is advisable to discuss the new development with the relevant government department(s) early in the development process to get advice regarding regulations and design considerations. In terms of the act, no person may alter or demolish any structure or part of a structure that is older than 60 years without a permit issued by the relevant Heritage Resources Authority. Such a permit is dependent on the grade of the building. Specific procedures must be followed where a new development involves any addition to or alteration of a heritage resource.

The concept of cultural landscapes is included in heritage conservation and management. Cultural landscapes are described as "the combined works of nature and man" and typically include landscapes, historic places, sites, and built environments. Landscapes include agriculture and historic vegetation. Examples of cultural landscapes are avenues, squares and parks surrounded and/or defined by historic trees; designed and formal gardens; places and vegetation of symbolic value, e.g. a slave tree; groups of trees planted for shade or windbreaks; old water courses and historic domestic gardens.

Appropriate development will strengthen and enhance the value of the resource for everyone and will often add value to the resource itself.

(vi) Adjacent land uses and edge conditions

Adjoining properties have an impact on each other. Therefore, it is important to be aware of the land uses adjacent to the development site, as well as the edge conditions that affect the site. Some of the questions that need to be asked include the following:

- What are the adjacent land uses and how could that potentially influence decisions regarding the layout and structure of the proposed development?
- Are there neighbouring buildings where privacy needs to be respected?
- Are there unattractive neighbouring uses from which the new development needs to be screened?
- Are there existing streets and spaces adjacent to the site to which the new development should relate?
- Are there noise problems from road traffic, railways or adjoining buildings?
- Is there neighbouring vegetation that may be affected by the development of the site?
- Does a waterway run along the edge of the site?

(vii) Access to the site

Any development must be connected to the rest of the neighbourhood and to the settlement as a whole. If there are no existing access or connection points available, there may be cost and time implications. Also, the street layout is influenced by the location of access points, existing footpaths and routes, and public transport facilities. The following questions need to be asked:

- What are the existing and potential vehicular, cycle and pedestrian access points to the site?
- Are there existing footpaths or other routes (desire lines) across the site? Can the existing footpaths and routes be accommodated in the new development? These desire lines should be considered when designing movement networks, as NMT users tend to follow established routes.
- Where are public transport facilities located in relation to the site?
- What are the local destinations (such as shops, schools) that occupants of the new project will be wanting to access? How can the new development best be linked to these to encourage walking and cycling?

F.3.2.2 Available engineering infrastructure and transportation facilities

Developments create additional demand for services (engineering and transportation) and therefore have a potential impact on existing engineering infrastructure (e.g. water pipelines, electricity cables, sewerage pipes) and transport infrastructure (e.g. streets, sidewalks, crossings, cycle paths). Infrastructure provision and settlement layout are intrinsically linked; therefore the following questions need to be answered:

- What engineering infrastructure (bulk and local) is available close to the new development?
- Does the existing engineering infrastructure have enough capacity to accommodate the new development?
- Can the new development be linked to existing engineering infrastructure?
- Are there public transport routes close to the site? Are there bus stops, railway stations or taxi ranks close to the site? Is there sufficient public transport capacity in the area?
- Are there cycle and pedestrian facilities available?

F.3.2.3 Existing socio-economic features

The planning and design of a development must be guided by the potential needs of the residents of the new and existing neighbourhoods. If an existing community will move into the proposed development, it is critical to understand the community and involve them in the decision-making process from the outset. (See Section E.) It is also important to acquire information regarding the socio-economic features of the neighbouring communities. This will provide some indication of the types of supporting land uses that may be required. The following questions should be asked with respect to the existing community (if known) and the the adjacent neighbourhoods, especially those that are functionally linked to the proposed development:

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

F.3.2.4 Access to existing social facilities and economic nodes

To determine the requirements for social facilities and economic nodes in the proposed development, the number of existing facilities in the neighbourhood, the services they offer, as well as the capacity of these facilities should be determined. The following questions could be asked:

- What types and how many social facilities are available in the neighbourhood, in adjacent neighbourhoods and in the settlement? See **Section H** for a discussion on the different types of social facilities.
- Are these facilities within acceptable reach of residents of the neighbourhood? Do these facilities have spare capacity?
- Will the community be using public or private facilities? This may be relevant to healthcare, education or recreation facilities.
- How many economic nodes are in the neighbourhood and in adjacent neighbourhoods?
- What are the sizes of these economic nodes? Are these nodes within acceptable reach to serve the residents of the proposed development?

F.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. It is best to deal with the following issues early in the development planning process:

(i) Land use scheme

Each property in a municipality is regulated by its zoning. The regulations associated with each type of zoning are contained in the land use scheme and typically deal with height, coverage, building lines, parking requirements, and residential densities. The following questions should assist to determine whether the proposed development will be allowed without having to apply for a rezoning, a consent use or another departure from the scheme (e.g. through a building line relaxation):

- What is the zoning of the property? What are the regulations attached to this zoning?
- Are there any other stipulations relevant to the site contained in the land use scheme?

(ii) Title deed(s) of the site

Settlement development is also regulated by conditions of title as set out in the title deed of each property, which can be obtained from the national or provincial deeds offices. The function of these conditions is to restrict or inhibit certain types of development on relevant properties. The conditions may have to be removed through a separate application to the local municipality. Development restrictions are also sometimes stipulated as part of the township establishment process and have to be considered (specifically when planning a brownfield development). Conditions in the title deed or in the township establishment scheme may affect the proposed street layout.

(iii) Site diagram

The site diagram, which can be obtained from the national or provincial deeds offices, the local municipality or a land surveyor, will provide valuable official information on the site. This information might affect the street layout and include the following:

- The extent or size of the land unit and the exact lengths and directions of the property boundaries
- Any servitudes registered on the land unit

F.3.3 Neighbourhood layout and structuring options

Neighbourhood layouts consist of streets, blocks and plots. Streets could include a number of elements, including space for moving vehicles (motorised and non-motorised transport), space for parked vehicles and space for engineering infrastructure (stormwater channels and trenches for sewers, water pipes, stormwater pipes, electricity cables and telecommunication cables). A street block can be defined as the smallest part of a settlement enclosed by streets. A plot is defined as a measured piece of land that forms part of a block, and it is also referred to as an erf, a stand or a site.

There are numerous ways in which street layouts can be designed and neighbourhoods can be structured. For the purposes of this Guide, the street layout and structuring options have been categorised as layouts resulting from a top-down approach and those resulting from a bottom-up approach.[17]

The top-down and bottom-up approaches result in a range of street layout patterns. In practice, there may not always be a clear distinction between street layouts and patterns resulting from a top-down approach and those resulting from a bottom-up approach. In general, though, bottom-up approaches result in street layouts that are more organic than those developed in a top-down manner.

The following street layouts are described in more detail:

Top-down approach
- Traditional/orthogonal grid
- Liquid grid
- Warped parallel grid
- Fragmented parallel grid
- Loops and cul-de-sacs
- Fused grid

Bottom-up approach
- Superblock approach
- De facto approach

F.3.3.1 Top-down approaches to street layout

Top-down street layouts are designed by the public and/or private sector and are predominantly applicable to greenfield or brownfield developments.[18,19,20,21]

(i) The traditional/orthogonal grid street layout

This grid pattern is a system of parallel streets crossing at right angles to form a pattern of rectangular blocks (Figure F.4). The grid is regarded as a permeable form of neighbourhood layout. It usually allows for easy movement within a neighbourhood (motorised and non-motorised transport).

Characteristics of the traditional grid street layout
• The grid is usually permeable and motorised and non-motorised traffic are able to circulate freely within the neighbourhood. • The intersections of the grid are often used for economic activity. • The grid is adaptive, and plots can be consolidated or subdivided with relative ease. • Finding one's way around a grid street layout is generally relatively easy. • The high degree of accessibility of the grid often results in higher costs because there are more interchanges and extensive road surface. • If applied to hilly sites, the grid can lead to steep street gradients, which increase the cost of drainage and sewer reticulation. • The straight streets of the grid layout make speeding (and often also ignoring stop signs) easier. • Surrounding traffic often cuts through neighbourhoods with grid layouts to avoid traffic lights or clogged highways. • The grid layout is sometimes viewed as monotonous and can result in plain, characterless neighbourhoods. • The grid street layout has numerous intersections and stop signs at most intersections, which could be frustrating for motorists.

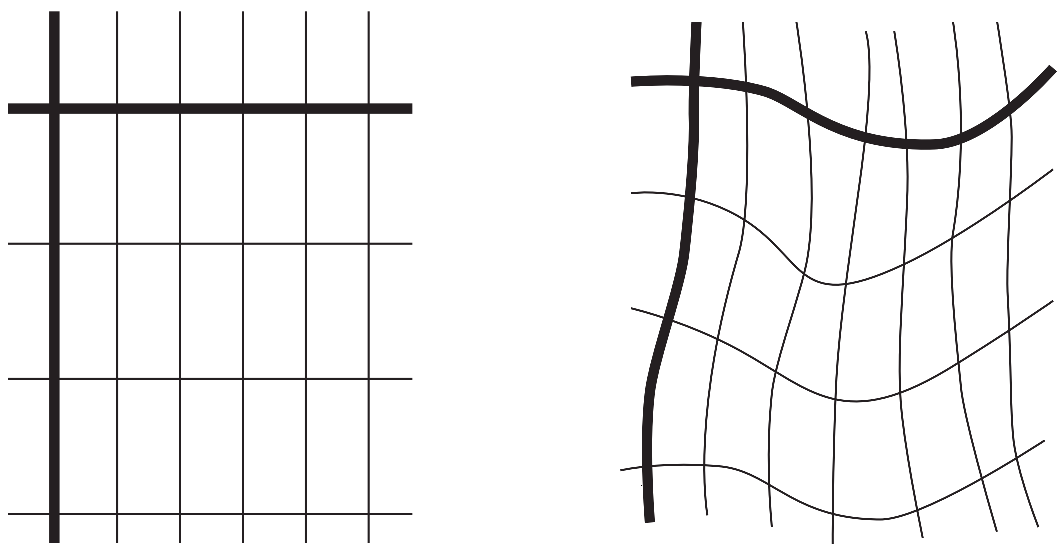


Figure F.4: The traditional grid street layout (L) and the liquid grid street layout (R)

(ii) The liquid grid street layout

This type of grid is sometimes referred to as a non-orthogonal grid, meaning that the streets do not have to meet at right angles (Figure F.4). The liquid grid is permeable and allows motorised and non-motorised transport to circulate freely within the neighbourhood.

Characteristics of the liquid grid street layout
• The curved streets of the liquid grid could discourage speeding. • The liquid grid is not monotonous as no two blocks are shaped exactly the same. • The liquid grid can be adapted for steep slopes and different landscapes. • It is relatively easy to find one's way around a neighbourhood with a liquid grid. • The high degree of accessibility of the liquid grid often results in higher costs because there are more interchanges and extensive road surface. • The curvy streets of the liquid grid can increase the cost of engineering services. • Surrounding traffic often cuts through neighbourhoods with liquid grid layouts to avoid traffic lights or clogged highways. • The liquid grid has numerous intersections and stop signs at most intersections, which could be frustrating for motorists.

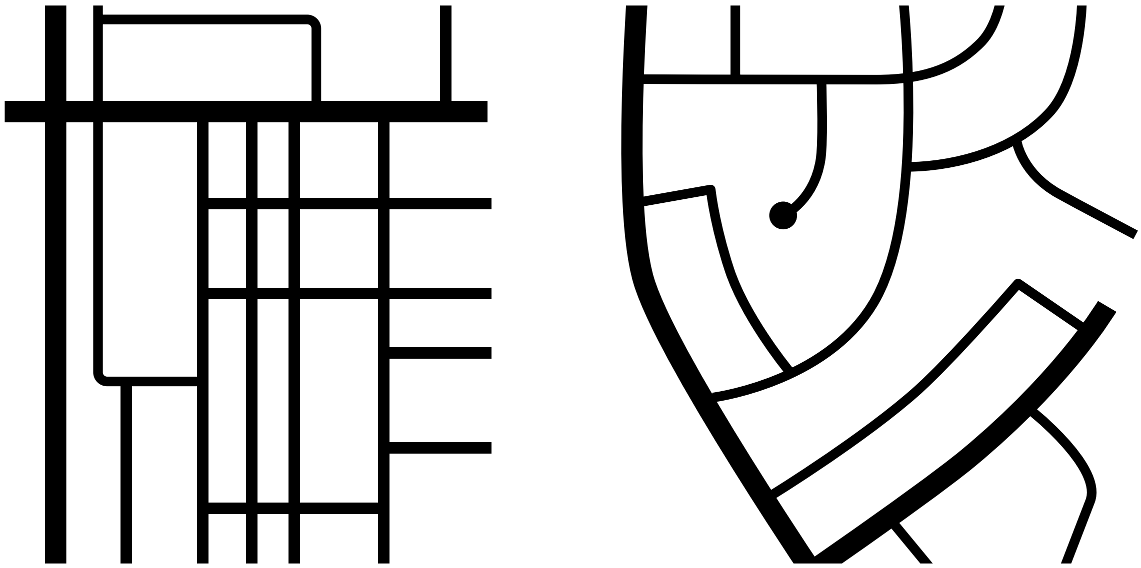


Figure F.5: The fragmented parallel grid street layout (L) and the warped parallel grid street layout (R)

(iii) The fragmented parallel grid street layout

The blocks of this type of layout form long, narrow rectangles and L-shapes (Figure F.5). Most crossings turn into T-intersections or L-shaped corners. Although this layout pattern's street lengths are similar to those of the traditional grid, it has fewer blocks and access points.

Characteristics of the fragmented parallel grid street layout
• The fragmented parallel street layout has fewer interchanges, resulting in lower costs. • The fragmented parallel street layout is not as accessible as the traditional grid, therefore surrounding traffic does not tend to take 'short cuts' through the neighbourhood. • The reduced number of access points makes the neighbourhood less permeable than the traditional grid layout. • The long, rectangular street blocks and straight streets are sometimes viewed as monotonous and can result in plain, characterless neighbourhoods. • Finding one's way around a fragmented parallel street layout is not always easy. • The fragmented parallel pattern is relatively pedestrian-friendly, although the longer block lengths often increase the distance pedestrians have to cover.

(iv) The warped parallel grid street layout

The warped parallel grid street layout has long and narrow blocks with T-intersections and L-shaped corners, but the streets are curvilinear rather than straight (Figure F.5).

Characteristics of the warped parallel grid street layout
• The warped parallel grid street layout has fewer interchanges, resulting in lower costs. • The warped parallel grid street layout is not as accessible as the traditional grid, therefore surrounding traffic does not tend to take 'short cuts' through the neighbourhood. • The warped parallel grid street layout can be adapted for steep slopes and different landscapes. • The curved streets of the warped parallel grid street layout discourage speeding. • The layout is not monotonous as no two blocks are shaped exactly the same. • The warped parallel grid street layout is not very pedestrian-friendly because of the curvy streets and the longer blocks. • Finding one's way around a warped parallel grid street layout is not always easy. • The reduced number of access points makes the neighbourhood less permeable than the traditional grid layout.

(v) The loops and cul-de-sacs street layout

This curvilinear and disconnected layout is sometimes referred to as the 'loops-and-lollipops' layout (Figure F.6). The layout is a combination of two patterns: loops, which are a common form of access street, and cul-de-sacs (dead-end streets). Access to the neighbourhood is provided by one or two higher-order streets. This street layout has become synonymous with the growth of suburbia worldwide during the 20th century. The pattern is often found in gated communities and lower-density neighbourhoods.

The 'lollipop-on-a-stick' layout is a variation on the theme and is formed by branching off cul-de-sacs from a few through streets (Figure F.6).

Characteristics of the loops and cul-de-sacs street layout
• The loops and cul-de-sacs street layout has few access points, reduces vehicular movement through the neighbourhood and creates quiet streets that are relatively safe for pedestrians. • The layout can be adapted for steep slopes and different landscapes. • In certain cases, the cul-de-sac can also be utilised as an activity or play area, thus reducing the requirement for public open space in the overall layout. • Engineering servicing costs can be reduced as the plots surrounding the cul-de-sac are serviced by way of an extension of the main service line. • The loops and cul-de-sacs street layout constrains pedestrian movement as the layout is not permeable. Pedestrians have to walk long distances to get to their destinations. • Waste removal trucks are sometimes too large to enter the cul-de-sac, especially if no turning spaces are provided. • Stormwater management should be carefully planned to ensure that water can drain out of the cul-de-sac. • Access from a cul-de-sac can be difficult if the traffic at the open end becomes undesirably high. This can be the result of streets that are too long and access that is provided to too many homes. • A blockage at the open end of a cul-de-sac can obstruct access to the interior plots. • Large loops and cul-de-sacs neighbourhoods force many drivers into one or two streets to get out of the neighbourhood, which causes bottlenecks, especially during peak hours. • It is not easy to find one's way in a neighbourhood with loops and cul-de-sacs.

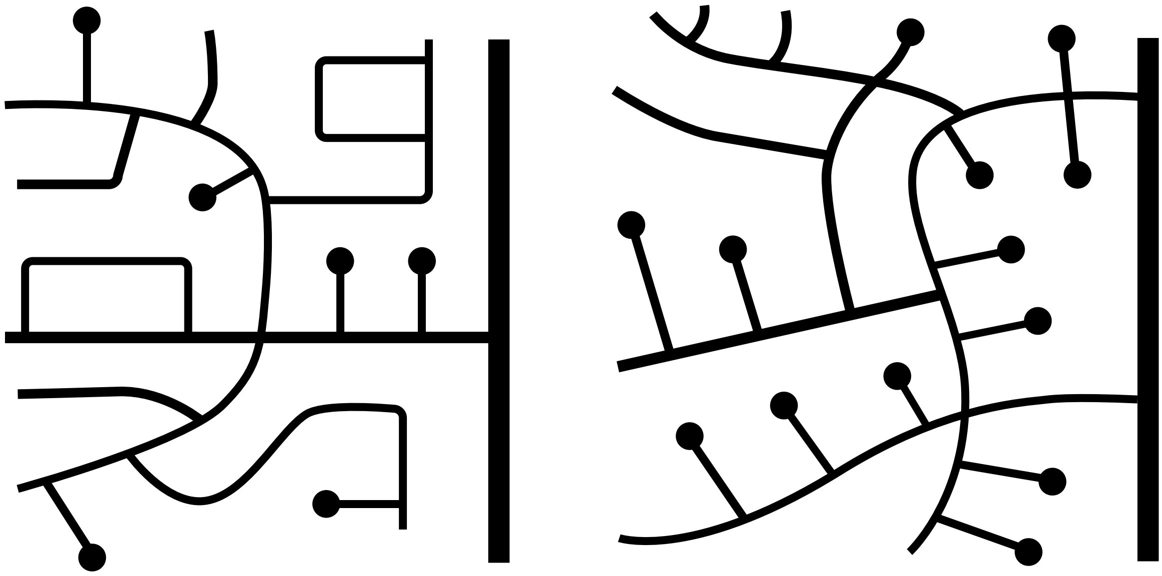


Figure F.6: The loops and cul-de-sacs street layout (L) and the 'lollipop-on-a-stick' street layout (R)

(vi) The fused-grid street layout

The fused grid represents the synthesis of two approaches to street layout: the traditional grid and the curvilinear pattern of looped streets and cul-de-sacs (Figure F.7). The goal of the fused grid is to provide a balance between vehicular and pedestrian movement, and to create safe, sociable streets and easy connectivity to community facilities.[22] This layout combines a continuous grid of streets for regional connectivity, and a discontinuous grid of streets for neighbourhood safety. The discontinuous grid of streets is supplemented by footpaths that connect all streets.

The fused grid further anticipates and directs land intensification and mixed uses by creating a zone with 'high potential for change'. It can also accommodate adaptations to future traffic demand.[23]

Characteristics of the fused-grid street layout
• The hierarchical street system of the fused-grid layout provides for efficient traffic flow. • The fused-grid layout can be applied to both inner-city and suburban contexts. • The combination of the continuous and discontinuous grids allows for the optimal use of land for streets. • Vehicular movement through the neighbourhood is limited. Quiet streets are created that are safe for pedestrians. • The fused grid is permeable, allowing traffic and pedestrians to circulate freely within the neighbourhood. • The fused grid can turn a neighbourhood into a fully connected pedestrian realm. • The fused grid encourages walking, while positively discouraging short-distance driving.

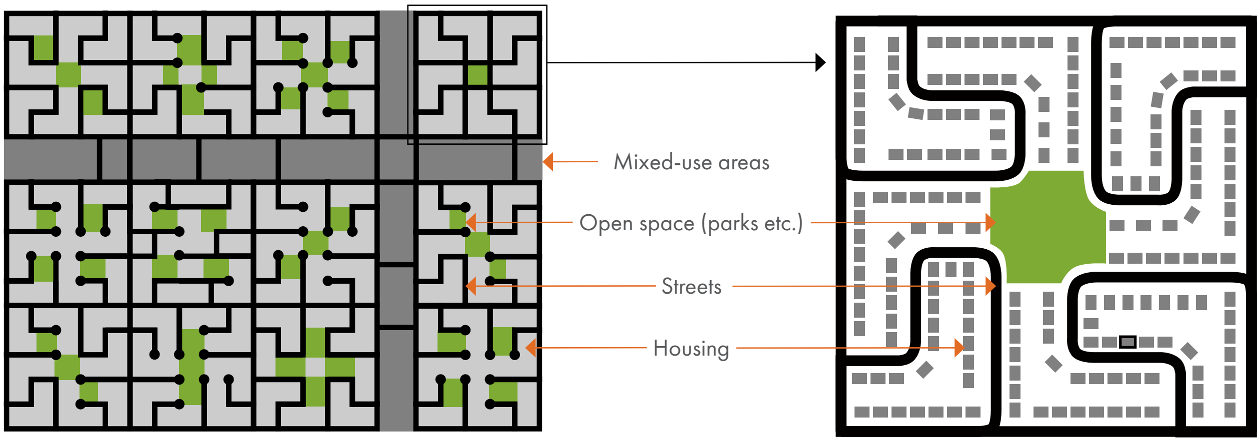


Figure F.7: The fused-grid street layout

Application of the layout options: Fine-grain versus superblocks

Two distinct approaches to top-down layout design can be identified.[24] One is referred to as the fine-grained multifunctional approach. It is usually associated with compact city-inspired mixed-use neighbourhoods where TOD projects cluster people and destinations together (see **Section F.2.3.4**). With this approach, blocks tend to be small and the permeability is high.

The other approach involves the use of so-called superblocks (not to be confused with the superblock layout discussed in F.3.3.2). The fused-grid layout is sometimes used to implement the superblock concept. It involves keeping motorised vehicle traffic on the outside of the development as far as possible. Movement in the central area of the superblock is mainly by NMT.

The superblock concept, also referred to by some as the courtyard concept (Figure F.8), allows for higher densities and creates safe (from traffic and from crime) and pedestrian-friendly public spaces for play and movement. To ensure an appropriate human scale, higher-density double storey units should be located next to the courtyards, while single storey units should front onto the surrounding streets. However, this configuration may vary depending on site-specific constraints and requirements. The superblocks are used as 'building blocks' for an entire precinct, enabling NMT users to move easily and safely through a precinct, with few higher-order streets to cross.[25]

Credit: Images supplied by the City of Cape Town

Figure F.8: Example of the superblock concept as applied in Cape Town

F.3.3.2 Bottom-up approaches to street layout

Layouts (usually in informal settlements) are sometimes created as people build and use a neighbourhood. The bottom-up approach is often employed when streets that developed spontaneously in informal settlements have to be formalised as part of in-situ upgrading initiatives. The street layout is therefore dependent on existing features and is often the result of extensive community participation. The following examples, which demonstrate various ways in which the bottom-up approach could be employed, are proposed and discussed in more detail in the *National Upgrading Support Programme (NUSP) Resource Kit.*[26]

(i) The superblock layout approach

The superblock approach is usually applied as part of incremental upgrading projects in higher-density areas where there is little space between existing housing units (Figure F.9). It is based on an initial assessment of existing movement routes, pathways and desire lines. This informs the proposed movement network and public space structure. The resulting movement routes create a number of large land parcels, or superblocks, containing several housing units.

Characteristics of the superblock layout approach
• Since this is an in-situ process that makes use of existing movement tracks, pathways and desire lines, it minimises displacement (see Figure F.9). • The process could be completed relatively quickly, since individual household boundaries do not have to be taken into consideration. • The approach allows for the provision of interim collective service infrastructure. • Superblocks facilitate the provision of incremental tenure and provide communal land security in the short term. Superblocks can be subdivided over time if required to accommodate individual freehold tenure.

Photo credit: Adapted from NUSP[27]

Figure F.9: Hypothetical example of the superblock layout approach - desire lines (L) creating large land parcels (R)

(ii) The de facto layout approach

This approach requires an understanding of the land boundaries of individual plots as perceived by each household. Once mapped, the rudimentary boundaries reveal the movement routes and pathways (Figure F.10). The exact plot boundaries need to be negotiated with the residents. Movement routes can then be demarcated for vehicles and, if enough space is not available, for pedestrian lanes. The de facto approach is most effective in areas that are not too dense, for instance where houses are located on a plot, with some yard space around them.

Characteristics of the de facto layout approach
• This approach requires engagement with every household, which could assist in securing general support for the eventual layout. • The process results in the formalisation of individual plots that are suitable for individual freehold tenure. • Since existing plot sizes form the basis of the layout, the final, formalised plots are often of different sizes (see Figure F.10). This could lead to tension between community members. • The irregular layout that often results from this approach could increase the cost of providing services infrastructure (for instance, the layout may require more pipe joints and manholes).

Photo credit: NUSp[28]

Figure F.10: Example of the bottom-up de facto layout approach

Re-blocking/blocking out

'Re-blocking' or 'blocking out' are terms used by the South African Shack/Slum Dwellers International (SDI) Alliance[29] to describe an approach to in-situ informal settlement upgrading that involves the repositioning of shacks (informal dwellings) based on a spatial framework developed by the community. The process is used to mobilise the community and to involve them in the spatial reconfiguration of the area in which they live.

This approach is usually implemented in informal settlements with relatively high densities. A key focus is the development of communal spaces that would benefit the community as a whole. These spaces can be used for movement, for providing communal amenities, or for providing services such as water, sanitation and electricity. Re-blocking is done in such a way that clusters of dwellings are grouped together to form courtyards. The dwellings face the courtyard to improve safety and provide space for washing lines, food gardens, etc. Re-blocking also creates space to provide protection against the spread of fires and provide access for emergency vehicles in case of disaster.

Figure F.11 shows the informal settlement before re-blocking commenced and the proposed intervention in Mshini Wami informal settlement in Cape Town.[30]

Photo credit: CORC

Figure F.11: The informal settlement before re-blocking commenced (L) and the proposed intervention (R)

F.4 Design considerations

Designing new neighbourhoods or improving existing ones requires an understanding of the many components and layers that create a well-functioning neighbourhood, and in particular how they should be assembled and integrated. Neighbourhoods consist, among others, of an arrangement of blocks, streets, buildings, open space and landscape. To a large extent, the interrelationship between all these elements (rather than their individual characteristics) determines the characteristics and the sense of place of the neighbourhood.

The structure provided by the street and plot layout creates a coherent framework that forms the basis of the design of individual projects that aim to achieve the objectives discussed in **Section F.2.2**. The way streets are laid out and how they relate to the surrounding buildings and spaces have a major impact on the aesthetic and functional success of a neighbourhood.

Good quality development is sensitive to its site and the surrounding area. A thorough understanding of the context, as described in **Section F.3**, sets the scene for a design response that is thoughtful and will likely result in development that provides a sense of 'belonging' to the area.

The creation of layout plans involves the detailed design – to scale and on a map – of the elements defined in concept plans. It involves making decisions about issues such as the dimensions of streets and public spaces and the extent of land needed for social facilities. In essence, it entails assigning widths, lengths and areas to the lines drawn on a concept plan.[31] The following elements should be considered when preparing a neighbourhood street layout plan:

- Streets
- Blocks and subdivision of plots
- Engineering infrastructure
- Social facilities
- Land use
- Public open space
- Neighbourhood identity

The layout design process
Designing a neighbourhood's street and plot layout is an iterative process. Often, satisfying one consideration will make it difficult to satisfy another, and invariably a balance has to be struck. For instance, when a decision has to be made regarding the subdivision of plots, it is important to consider the housing type to be accommodated in the development as well as the other land uses required (public open space, social facilities, etc.). At the same time, the physical conditions on the site have to be considered as well as the cost implications of the various options available for the layout of streets, the subdivision of plots and the provision of engineering infrastructure.

F.4.1 Streets

For the purposes of this Guide, the terms ‘roads’ and ‘streets’ are used interchangeably, referring to any pathway that is intended to accommodate and facilitate the movement of pedestrians, cyclists, wheelchairs, motor cycles, animal-drawn carts, motor vehicles, etc. as well as other activities that may take place in neighbourhood streets. The focus is specifically on the neighbourhood street, which has to respond to the local conditions and has to accommodate both motorised and non-motorised traffic as well as a range of other activities. For a more detailed discussion on the planning and design of transportation and road pavements in a neighbourhood, refer to Section I.

A neighbourhood’s street layout has a significant and lasting impact on the functioning of the neighbourhood. Facilitating movement is a key function of streets, but they fulfil other functions as well, including the following:

- Creating a sense of place by linking buildings and spaces that are on the edge of the street
- Providing access to buildings and public spaces
- Allowing for parking of vehicles
- Providing space for interaction and play
- Accommodating engineering infrastructure including electricity, water supply, sewerage and stormwater drainage

In addition to the above, streets could also play other roles, influenced by the neighbourhood that streets are located in, the land uses, the activities and the people. The current and envisaged local context of a street is a critical factor to consider when planning and designing the street layout of a new development. What is appropriate in one setting may be out of place in another neighbourhood (see Figure F.12).

Photo credit: Chris Kirchhoff (L); Jeffrey Barbee (R) - www.brandsouthafrica.com

Figure F.12: Streets can fulfil a range of functions

In many cities, streets provide the only place for some people to live. The street is their home, and it may be the only home they will ever know. In some cases, families have come to accept that they will always live on the street, and that they need to make the best of the situation. When this is part of the local context, streets should be designed to accommodate people living under these circumstances.

Designing streets for place

The 'Global Designing Cities Initiative' explains the idea that streets should be designed for place as follows:

"Designing streets for place means considering the local culture and context. The specific characteristics of each site should help identify the uses and functions the street design must support. Shape streets to improve not only the built, but the natural, social, cultural, and economic environments. Whether changing the configuration of an existing roadbed or planning new neighborhoods, street design must always carefully consider the nature of its context. Streets have the power to drastically catalyze change in neighborhoods, or to enhance, protect, and improve what is already there.

Consider local culture and climate to ensure that the streets support daily routines, rituals, and behaviors. Provide access to new mobility choices and invite people to feel comfortable in their neighborhoods at all times of the day. Analyze what the street means, as a place, to the people who live and work nearby. Document how and when they use the street. Engage local communities and involve them in the process of transformation to ensure the adoption and long-term stewardship of the street.

As contexts change over time, mobility needs, activities, and behaviors will shift, and street designs should be chosen to best support current and future community goals and priorities."[32]

Figure F.13: Streets play various roles and could contribute to the character of an area

To design a street layout that will assist in reaching the objectives outlined in **Section F.2.2**, a number of factors should be considered. These factors are discussed next.

F.4.1.1 Layout permeability

A street network that has many short links, numerous intersections and few dead-end streets are referred to as permeable (Figure F.14). In a permeable street layout, travel distances decrease and route options increase, allowing more direct travel between destinations.[33]

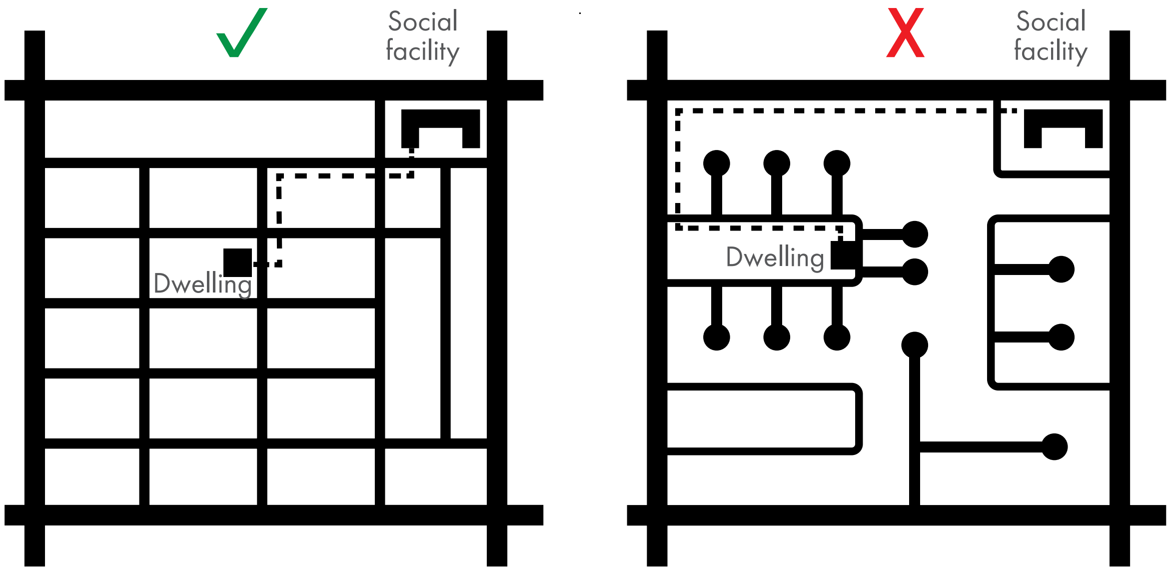


Figure F.14: The street layout on the left is more permeable than the one on the right

Permeable layouts encourage walking and cycling and allow for easy navigation through the neighbourhood. They also lead to a more even spread of motor traffic throughout the area, but at the same time it may be difficult to keep vehicles out of neighbourhoods. To ensure that street layout is permeable, consider the following:

- Provide direct connections between key facilities.
- Avoid dead-ends in the street layout as far as possible. If this is not possible, make use of cul-de-sacs, but be aware that they could easily result in an introverted neighbourhood that is not effectively integrated into the surrounding area. A layout with loops and cul-de-sacs often results in longer routes for pedestrians than grid-type layouts (see Section F.3.3.1). If cul-de-sacs have to be included in the layout, for instance due to steep inclines or other site restrictions (see Section F.4.1.4), consider providing pedestrian pathways between the heads of adjacent cul-de-sacs. Also ensure that space is allowed in the head of the cul-de-sac for large vehicles to turn around.
- If working with a greenfield site, identify existing routes and/or pedestrian desire lines across the site and accommodate these in the new layout (Figure F.15).
- In certain cases, permeable neighbourhood layouts could provide access and escape routes that may increase opportunities for crime. However, such layouts could also reduce opportunities for crime if pedestrian activity is encouraged. It is essential that the principles of Crime Prevention through Environmental Design be carefully incorporated into a development to reduce opportunities for crime (see Section O.1). Improve the safety of pedestrians and cyclists by, for instance, developing routes that are well lit, are not flanked by blank walls and do not cut across vacant or derelict land.

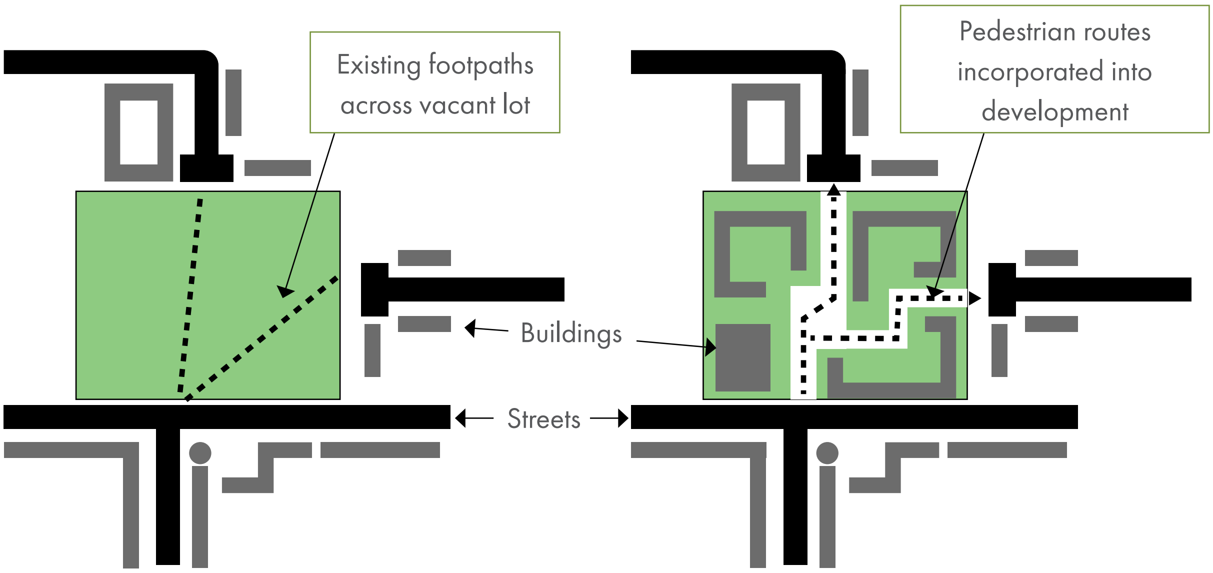


Figure F.15: Incorporate existing pedestrian routes into the layout where appropriate[34]

F.4.1.2 Linkages to the surrounding area

The proposed development should be connected to the surrounding area. A development with poor links to the surrounding area creates an enclave that encourages movement to and from it by car rather than by other transport modes. To link a layout to the surrounding area, consider the following:

- Where possible, provide direct connections to main streets that carry through-traffic.
- Ensure that new developments are not cut off from key activity centres or social facilities by higher order roads. This can create dangerous conditions where pedestrians might still attempt to cross these higher order roads.
- Link the development with the surrounding movement networks through identified points of connection and by extending important routes through the development to strengthen inter-neighbourhood connections.
- Link the development with existing public transport routes and facilities that are near the site. Provide opportunities for existing public transport to pass through the neighbourhood.

F.4.1.3 Street hierarchy and layout

The nature and types of streets to be provided in a neighbourhood, and the related hierarchy and layout, should be guided by the purpose of the different streets. Streets should be designed to suit the activities that will have to be accommodated, and to support activities that one would want to see happening on the street.

Making decisions regarding road classification

The South African Road Classification and Access Management Manual (TRH26) provides the following advice:

"Roads must be provided to suit land use and not the other way round. The road network is determined by the land use and it is the size, importance and density of destinations that need to be served that determine the number and class of road required to serve them."[35]

A well-considered street hierarchy can help create attractive and safe neighbourhoods (Figure F.16). For instance, by routing main distributor roads around a specific area and not through it, the quality of the area could be preserved.[36]

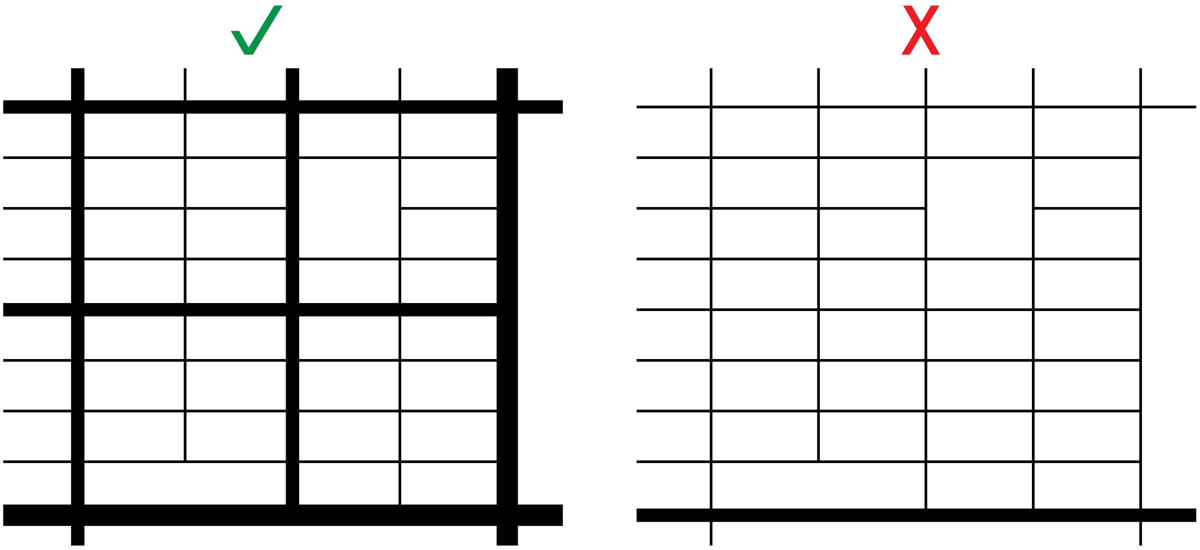


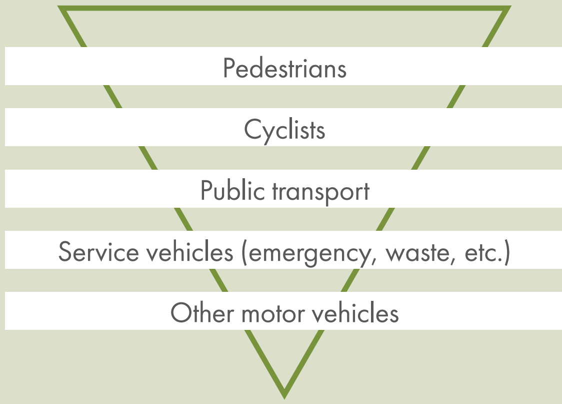
Figure F.16: A well-considered hierarchy (L) can help create a safe neighbourhood

A hierarchy of streets could assist in reducing conflict between through-traffic and local access-seeking traffic. Local conditions should guide the hierarchy, and care should be taken to consider all users of the streets, not only vehicle users. The separation of different types of traffic and road users may also not always be appropriate, and therefore a rigid hierarchy is not advisable. The following should be considered when preparing a hierarchical street layout:

- Identify streets currently used or likely to be used for public transport.
- As far as possible, do not connect a street of a lower classification directly to a street of a much higher classification. It is important to ensure a gradual change in function over the length of the trip to avoid different classes of streets affecting each other's operations.
- Identify the location of existing and proposed activities including economic nodes and social facilities. To create economic opportunities, traffic (both motorised and non-motorised) should be encouraged to pass through an area.
- Provide dedicated NMT facilities along higher-order routes.

Hierarchy of street users

In addition to multiple functions, streets also have multiple users. Often, different users have different requirements, and there is always a risk of conflict between them. A wide spectrum of needs have to be considered. One end of the spectrum relates to pure mobility, as typified by the freeway and urban arterial. Vehicle movement is the sole concern and pedestrians are totally excluded from these roads. The other end of the spectrum is concerned with accessibility and the needs of the pedestrian. Vehicular movement may be necessary on these roads but it is tolerated rather than encouraged and is subject to significant restrictions. Between these two extremes, mixed usage is found with vehicular and non-vehicular activities sharing the available space. To assist with decision-making when designing neighbourhood streets, the needs of the different users should be prioritised based on the local context and guided by the following hierarchy of users:



First consider the needs of pedestrians, followed by cyclists, public transport users, service vehicles (e.g. emergency services and waste removal), and then other motor vehicles.

It makes sense to prioritise the safety of the most vulnerable users, namely pedestrians and people with disabilities, since a safe, comfortable and attractive pedestrian environment would benefit all street users. However, streets do not all have the same purpose, and therefore the balance between different needs would be influenced by the specific circumstances. All activities should, as far as possible, be accommodated without them having to compete for space. This can be achieved by utilising the road reserve effectively and carefully designing the street cross-section (see Section F.4.1.5).

F.4.1.4 Street curvature and gradient

Street curvature refers to the horizontal alignment of streets. Critical considerations in the design of appropriate street curvature include the place-making function of streets, the sight lines of motorists, the contours of the landscape and the provision of engineering infrastructure.[37] The detailed design parameters for the horizontal alignment of streets are discussed in Section I.4. The following should guide the street layout of a neighbourhood:

- Use straight streets where possible to facilitate efficient service reticulation, specifically for stormwater, sewerage and above-ground electrical cabling. Significant cost and time savings come from having the shortest comparative service line lengths per plot, straight trenches and a minimum number of manholes.

- Align streets to follow slope contours, where possible. This minimises costly 'cut-and-fill' exercises and enables natural gravity-flow drainage to be utilised (see Figure F.17).
- If possible, avoid layouts that use unnecessary curves, as they are costly. However, curved streets may be required under certain conditions, for instance to accommodate topographical characteristics and constraints of the development site. In some cases, cul-de-sacs could be used instead of curved streets. When using cul-de-sacs, take the factors referred to in Section F.4.1.1 into consideration.
- Weigh the financial advantages up against non-financial factors. For instance, long, straight streets might cost less than curved streets, but they can lead to unsafe driving behaviour as they sometimes encourage speeding.

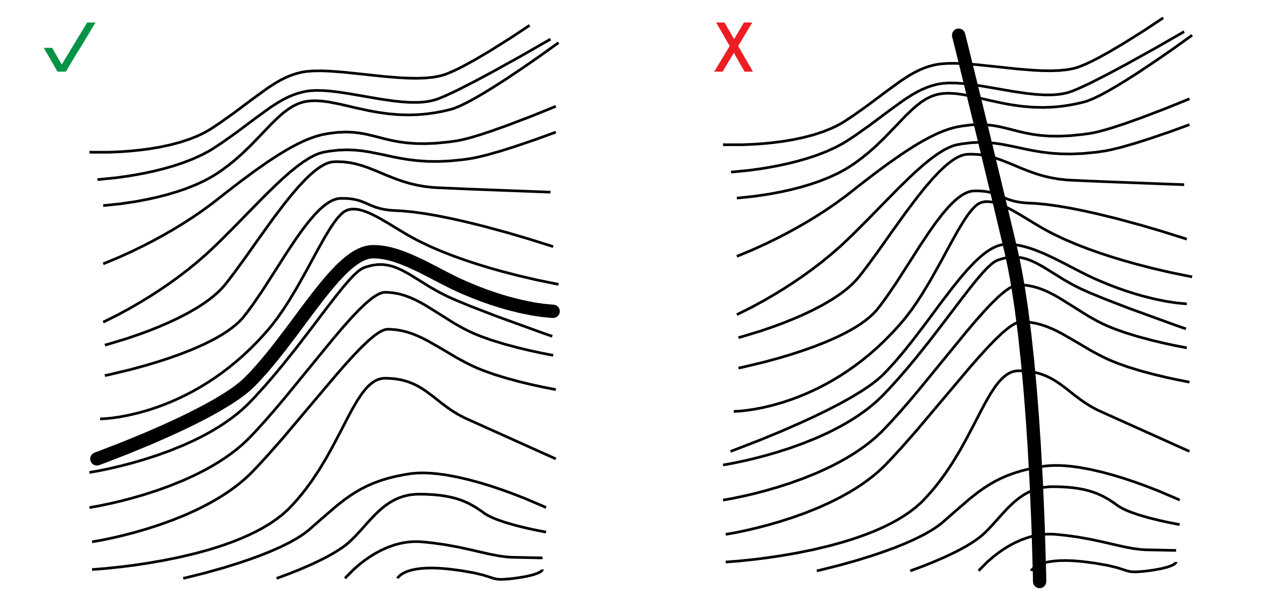


Figure F.17: Align streets to follow slope contours (L)

Street gradient refers to the vertical alignment of streets. Very steep or very flat street gradients present problems relating to the circulation of larger service vehicles and the flow velocities of gravity-based engineering services. The vertical alignment of streets also has significant implications for NMT users as steep gradients are relatively easy for motorised vehicles to negotiate, but can be prohibitive to NMT users. The Department of Transport[38] suggests that gradients along the paths of pedestrian and NMT travel should not be steeper than a ratio of 1:12 (8.33%), with a preferred ratio of at least 1:15 (6.66%). Access for emergency vehicles and service vehicles such as solid waste removal vehicles should ideally not be steeper than a ratio of 1:12. The detail design parameters for the vertical alignment of streets are discussed in Section I.4.

Steep gradients could have a significant impact on the cost of a development. Wherever possible, street alignment should be designed to minimise the extent and cost of earthworks and to avoid problems with access to plots. It is essential that the design of streets be coordinated with stormwater management design (Section L).

F.4.1.5 Street width and cross-section design

The cross-section of a road or street incorporates a number of components, collectively referred to as the road reserve. The road reserve is a designated area, or servitude, where certain buildings or structures and activities are not permitted. The cross-section of a road reserve comprises of two main components, namely the street or roadway, and the area between the roadway edge and the road reserve boundary, also referred to as the verge, shoulder or roadside. These two components could include various lanes for vehicular traffic, lanes set aside for public transport vehicles, parking spaces, medians (central islands), cycle lanes and sidewalks for pedestrians and NMT users.

The cross-section of a street could be designed to allow for a range of activities and users, including moving and parked vehicles, pedestrians and non-motorised vehicles such as cycles and wheelchairs. The road reserve could also accommodate engineering infrastructure and utilities such as stormwater drainage, water, electricity, communications and sewer trenches. Some of these elements can be found on the surface, while others are placed underground, either under the road itself or under the shoulder area. In addition to movement-related functions, street reserves can support recreational activities and social interaction between residents, serve as playgrounds for children, provide space for commercial activities (formal and informal trading), and they could provide a place to sleep (or even a home) to some.

Figure F.18: Road reserves can accommodate different functions depending on the context

It is evident that the width of street reserves would vary depending on the functions and activities that have to be accommodated (also see **Section I.4**). Some municipalities have developed their own specifications and guidelines, and information is also provided in *TRH26: South African Road Classification and Access Management Manual*[39] and in *TRH27: South African Manual for permitting services in the Road Reserve.*[40] The widths of road reserves, streets and lanes are dependent on the local context and would differ depending on various factors. The following should be considered:

- Under certain conditions, narrow streets, or even narrow lanes, could cause motorists to reduce speed, making for a more user-friendly streetscape and liveable neighbourhood. However, this may not always be the case, and care should be taken to ensure that narrow streets or lanes do not result in unsafe streets. The effect of the width of a street or lane on the speeds at which some motorists travel is influenced by various factors, including time of day and the number of vehicles on the road.
- The current and future purpose of the street, the traffic volume, and the type of vehicles that will be using it would influence the activities that could safely be accommodated on the shoulders and sidewalks.
- In some cases it may not be physically possible to provide a road reserve that includes more than space for a narrow street. For instance, the in-situ upgrading of an informal settlement sometimes presents a situation that challenges conventional approaches.

- Generally, a wider street means higher costs. It also affects the average cost of the individual plots adjoining it. Therefore, all factors, including the adjacent land uses and the scale of the buildings on either side should be carefully assessed to ensure, as far as possible, that the optimum street width is chosen.
- Topographical factors such as steep slopes may require additional space to allow for earthworks (cut and fill) within the reserve.
- In certain neighbourhoods, shoulders and sidewalks may be used for trading or light industrial activities, which would necessitate sidewalks wider than those required purely for moving pedestrians.
- Sidewalks may have to accommodate pedestrians that linger or 'park', for instance when they browse through goods on offer (either in shop windows or by roadside vendors), when they meet with friends, or when they patronise a sidewalk café.
- Dealing with stormwater challenges is often a critical factor that should be considered when deciding on the width of a street reserve and especially the width of the roadway itself (see **Section L**).

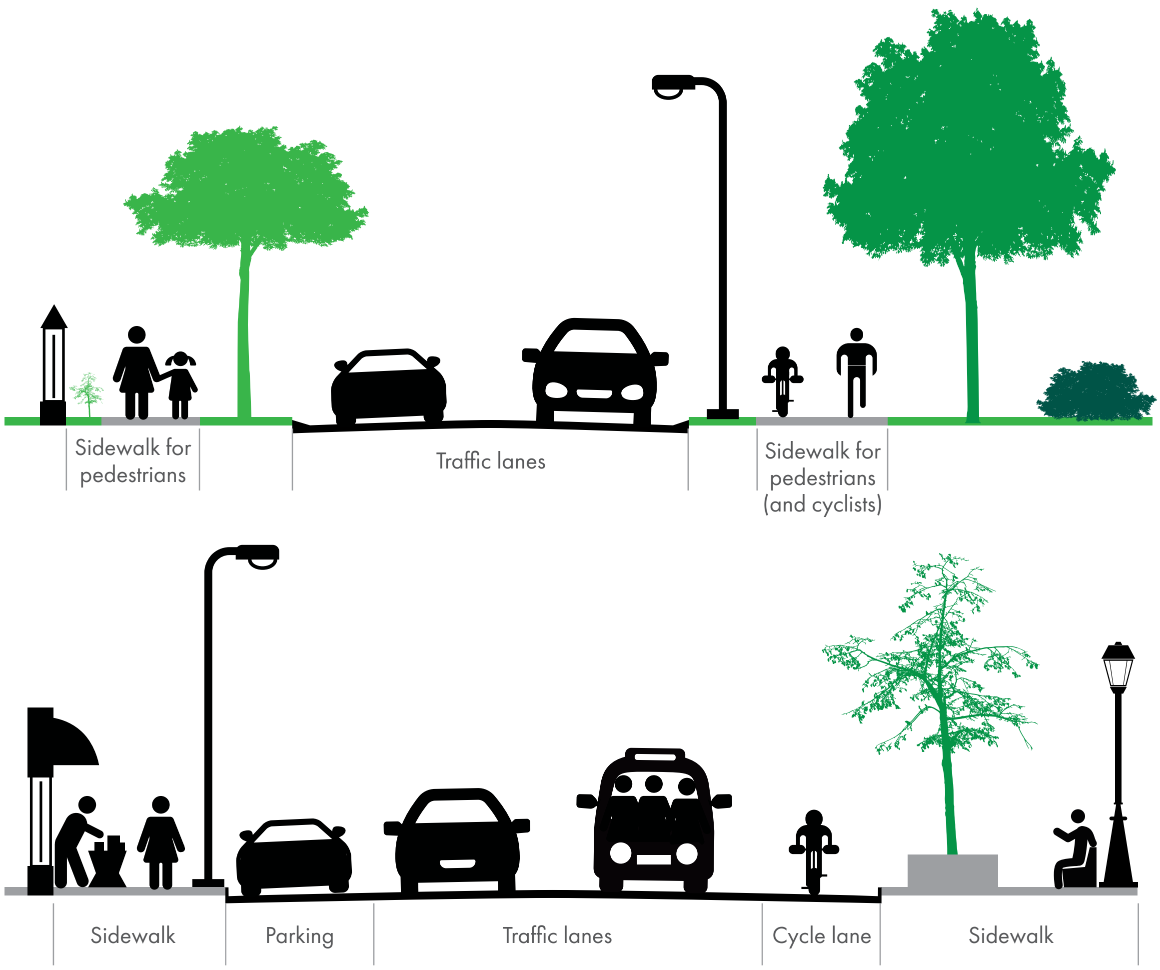


Figure F.19: Surface elements of the road reserve - examples of possible configurations

Figure F.19 illustrates typical surface elements of a road reserve. Not all these elements are always present, and the elements could be configured in a number of ways. Examples of possible permutations are demonstrated in this illustration, but more are possible. The elements included in the road reserve vary according to the availability of space, the specific needs of the neighbourhood and the costs involved in providing the various elements. The elements that could typically be included in a road reserve are discussed below.

(i) Roadway (street)

The roadway is the part of the road reserve that is used by motorised vehicles and usually has a hard surface (referred to as a pavement). The number of lanes to be provided and the width of each lane should be guided by the context, including the volume and type of traffic to be accommodated. Certain neighbourhood streets would consist of two lanes in each direction, separated by a median, while in some cases one narrow lane in each direction may be more appropriate. More information is available in *TRH26: South African Road Classification and Access Management Manual.*[41]

(ii) Sidewalks

Sidewalks should provide pedestrians with a safe and convenient space to walk, linger and participate in activities taking place on the sidewalk and surrounding spaces. The width and nature of a sidewalk is determined by several factors, including the following:

- The current or anticipated future pedestrian and NMT volumes
- The location of the street, for instance the CBD, a suburb or an informal settlement
- The proximity to potential current and future pedestrian generators such as schools and shopping centres
- The speed and volume of the traffic making use of the street related to the sidewalk, and the frequency with which heavy vehicles may make use of the street
- The types of activity that will take place on the sidewalk, including formal or informal trading
- The land use associated with the properties adjacent to the sidewalk and the activities they may generate, for instance restaurants using the sidewalk as an extension of the dining area

Photo credit: Chris Kirchhoff (R) - www.brandsouthafrica.com

Figure F.20: Sidewalks may have to be adapted to accommodate the various activities that could take place there

Universal access

Sidewalks should, as far as possible, cater for the needs of everybody and should be designed such that they can be accessed and used by all, whether they are disabled or not, and regardless of age, size, etc. Particular attention should be paid to decisions regarding materials and the design of components such as intersections, pedestrian crossings, traffic signals, signage and street furniture. More information is provided in Section O.2.

(iii) Cycle lanes

Cycle facilities are typically accommodated either on the roadway or as a cycle-exclusive route. Care should be taken to ensure the safety of cyclists, pedestrians and motorists, for instance by using different paving material, pronounced edges and lines to demarcate lanes. The width of the movement space, and the location of street trees and signage should be carefully planned to make it safe for cyclists who are moving at a reasonable speed.

(iv) Parking and loading space

When providing on-street parking and loading space, the operating speed of traffic should be considered, as well as the activities taking place on the sidewalk. Pedestrian activity should also be taken into account and care should be taken not to create a safety hazard by allowing cars to park on the street.

(v) Lighting and street furniture

If possible, pedestrian-scaled lighting should be provided on the sidewalk or on the median (the reserved area that separates opposing lanes of traffic on divided streets). Street furniture includes seating, rubbish bins, bicycle racks and signs. Where possible, these should be grouped and located such that they enhance sidewalk activities, allow clear pathways for NMT users and do not obstruct emergency vehicles or services.

Photo credit: Graeme Williams (R) - www.brandsouthafrica.com

Figure F.21: Lighting, street furniture and trees make streets more pedestrian friendly

(vi) Street trees and landscaping

Trees could be used to shade the sidewalk, improve air quality, enhance the character of the streetscape and generally improve the quality of a neighbourhood. Other plants and grass could also improve the appearance of a sidewalk and provide comfortable areas for people to relax. Different paving material may be used to demarcate areas, for instance indicating the areas reserved for trading and the areas that should be kept clear for pedestrians.

(vii) Public transport bays

On designated public transport routes (or potential public transport routes) provision needs to be made for facilities such as stops, shelters and embayments. Specific attention should be given to providing parking spaces in areas where minibus taxis may be the only form of public transport.

(viii) Engineering services reticulation

Engineering service infrastructure that can be accommodated in the road reserve includes stormwater channels, and trenches for sewerage pipes, water pipes, stormwater pipes, electricity cables and telecommunication cables. The challenge is to locate this infrastructure in a manner that meets operational requirements and does not interfere with movement. Care should be taken to restore the roadway or verge where it has been disturbed after construction. More information is provided in *TRH 27: South African Manual for permitting services in the Road Reserve.*[42]

F.4.2 Street blocks and the subdivision of plots

While considering street design issues such as linkages, permeability, hierarchy, curvature, gradient and width, the layout designer should also consider the street blocks that are created through the street layout, as well as the subdivision of these street blocks into different plots. Aspects that should be considered include the impact of the natural landscape on the layout, street block dimensions, plot dimensions and densities.

F.4.2.1 Layout implications of the landscape

When planning and designing the layout of a development and determining the optimal block and plot size and shape, consider the following:

- Design blocks and plots in such a way that buildings, streets and sewers follow slope contours. This reduces the need for earthworks and allows for natural gravity-flow drainage.
- Design street blocks and individual plots so that they will drain towards the street, where possible.
- Use irregular blocks where needed to adapt to the topography.
- Orientate the development to make the most of attractive views.
- Orientate blocks and plots so that buildings can be positioned to face north. If the long side of a plot faces north, the building could be orientated towards the sun, and this could potentially reduce the need for heating and cooling and make it easier to install solar panels.
- Make use of unique features of the landscape such as existing buildings, rock outcrops, large trees, waterways and other characteristics to guide the layout. These could act as focus points or be included in the open space network. Land not fit for human habitation or conventional construction could possibly be used as open space or as parking areas.

- Accommodate risk areas (e.g. dolomitic areas and the 50-year floodplain of streams and rivers), culturally sensitive areas (e.g. grave sites) and sites of ecological importance by including them as part of open space or as conservation areas, where possible. Bear in mind that these sites have to be maintained in years to come.

F.4.2.2 Street block dimensions

The dimensions (width and length) of street blocks influence the walkability of the neighbourhood, the engineering service reticulation, the safe spacing of street intersections and plot access. Decisions regarding block dimensions should be guided by the context of the development and the following should be considered:

- Optimise block widths for safety and convenience. Block widths of around 60 m are often considered as an optimum width.
- Limit block lengths to 100 m if possible, as some pedestrians may find it strenuous if blocks are very long. Shorter blocks allow pedestrians to follow the shortest route to their destinations and they also constrain vehicle speeds.
- Provide pedestrian pathways (crosswalks) through long blocks, should the latter be the only option available. By providing these pathways in the vicinity of shopping centres, schools or parks, pedestrians would not be forced to use circuitous routes to reach their destinations. These pathways must be clearly identifiable and well maintained.
- Where possible, orientate rectangular blocks with the short side onto the street with more activities, more land uses, etc. This can increase connectivity with the surroundings and provide more crossings and junctions, which would assist in slowing down traffic, making it easier for pedestrians and cyclists to move around. Residential buildings can then line the quieter (long) sides of the block.[43]
- Increase the number of plots from the conventional two-plot-deep block to a four-plot-deep block in cases where plots are very small. This will reduce the total amount of space that has to be allocated to road reserves in a development. Certain subdivision patterns, like panhandle plots or blocks with dissecting pedestrian-only routes, can increase the number of plots between road reserves. However, some of these subdivision patterns assume that the plots in the middle of the block will never require private vehicular access. Ensure that most properties are accessible by vehicle.

Walkable neighbourhoods

Walkable neighbourhoods can be defined as neighbourhoods that encourage and enable walking as a means of accessing different places or facilities.[44] A walkable neighbourhood should typically display the following characteristics:[45]

- **Traversable:** Basic physical conditions such as smooth and uninterrupted walking surfaces and appropriate pedestrian infrastructure allow people to get from one place to another without major hindrances.
- **Compact:** High-density, mixed-use and transport-orientated developments (see Section F.2.3) enable pedestrians to get from one place to another by only covering a short distance.
- **Safe:** Low-crime areas and areas where the rules of the road are respected by all enable pedestrians to reach their destinations safely.
- **Attractive:** Walkable neighbourhoods are pedestrian-orientated with high-quality pedestrian infrastructure, appropriate lighting and public furniture, useful signage, attractive street trees and other amenities.

Walkable neighbourhoods have many benefits, including increased physical activity of residents, reduced carbon emissions, more affordable transportation, less congestion, less sprawl and a 'richer' public domain.[46]

When planning and designing a walkable neighbourhood, attempts are often made to establish what a comfortable walkable distance would be and to then use this as a measurement of walkability. However, a wide range of factors will affect the distance that can be walked comfortably, including whether someone is disabled or not, the person's age, level of fitness, preferences and health status. The topography of the neighbourhood, physical characteristics such as rivers, streams and stormwater channels, and weather conditions will also affect walkability.

It is therefore challenging to identify a typical or average distance that can be regarded as a walkable distance. Often, the ease of walking is measured as the distance that can be reached within a certain time. In densely developed cities, a 5-minute walk to a destination is often regarded as convenient. Given the prevalence of low-density residential development in South African settlements (see Section F.4.2.4) and the low levels of personal mobility of large portions of the South African population, such a measure of walkability may seem ambitious. However, such convenient walking distances are technically achievable in the high-density, mixed-use and TOD zones promoted by a range of policies and plans. The use of access distances for the planning of social facilities is discussed in Section F.4.5 and in Section H.

In the broader South African settlement context, a walking time of between 15 and 20 minutes would probably be a measure of a more realistic comfortable (if not highly convenient) walkable distance. If a walking speed of 1 m/s is assumed, this would translate into a distance of between 900 m and 1.2 km.[47]

Walkable neighbourhoods involve more than just convenient walking distances. Such neighbourhoods are created when attention is paid to various factors, including block and plot sizes, pedestrian infrastructure, public furniture, housing typologies, densities, public transport and social facilities.

Engineering service reticulation also influences street block design, as the infrastructure conventionally follows the street layout. Manholes that are used for inspection of pipes and to clear blockages have to be placed at horizontal and vertical changes of direction, at junctions between main and branch pipe lines, at the head of a reticulation system and at intervals on straight stretches of pipe. These intervals on straight stretches of pipe should be spaced at approximately 80 m to 100 m from each other. Manholes can be expensive, and hence it follows that a layout with straight blocks will limit the number of manholes and save costs. Refer to **Section K 4.4** for additional guidance on manhole provision.

F.4.2.3 Plot dimensions

The range of plot sizes provided in a development has a significant impact on the mix of land use activities and the range of housing types that can be accommodated. In the case of detached housing (a single house on one plot), the size of the plot often determines the density of a neighbourhood. Generally, smaller residential plots would result in relatively high densities, but this would be dependent on the context and type of neighbourhood. For instance, in low-income communities, plots in the region of 75-100 m^2 would result in fairly high densities, while larger plots (in the region of 200-300 m^2) may initially not achieve the same densities. However, the bigger stands may provide opportunities for house extensions and back-yard accommodation that may result in a densification of the neighbourhood as time goes by.

> Development projects funded by government subsidies or grants should adhere to minimum norms and standards as specified in the National Housing Code.

The size of the plot influences its ability to accommodate change over time. A larger plot provides a flexible basis for future incremental growth to take place. (See **Section H.3.3.1** for a discussion on the link between density and housing type.) The following should guide decisions regarding plot size:

- Keep the street frontage of residential plots as narrow as possible to optimise engineering services provision. The overall cost for infrastructure provided along any given street stays more or less the same, regardless of the number of plots serviced along the street. Therefore, the narrower the street frontage of the plots, the larger the number of dwelling units that share in the cost of the infrastructure and the lower the cost per dwelling unit (see Figure F.22).
- Provide larger plots for retail, commercial, industrial or civic buildings. The appropriate size and location of these plots depend on the scale, nature and compatibility of the anticipated activity, as well as on their access and distribution requirements.
- Provide a range of plot sizes that can potentially accommodate different housing types or mixed uses (see **Section H.3.3.1**). Upgrading an informal settlement generally does not allow for uniform plot sizes as the plot sizes emerge through a process of dialogue between relevant parties, taking into account existing buildings, spaces, streets and pathways.[48]
- Provide higher-density residential plots adjacent to social facilities (e.g. clinics) and open spaces (soft and hard).
- Consider using panhandle plots to produce a four-plot-deep block, especially when plot lengths are less than 10 m, as it then becomes inefficient to design conventional two-plot-deep blocks. The four-plot-deep block will increase the width of the block in relation to its length and result in service cost reduction (see Figure F.22). Four-plot-deep subdivision patterns can offer reticulated engineering services at a much lower cost per plot. However, for various reasons, some people prefer plots with street frontages, for instance because of the trading opportunities they offer, because they enjoy the interaction with the street, or because it improves their sense of security.

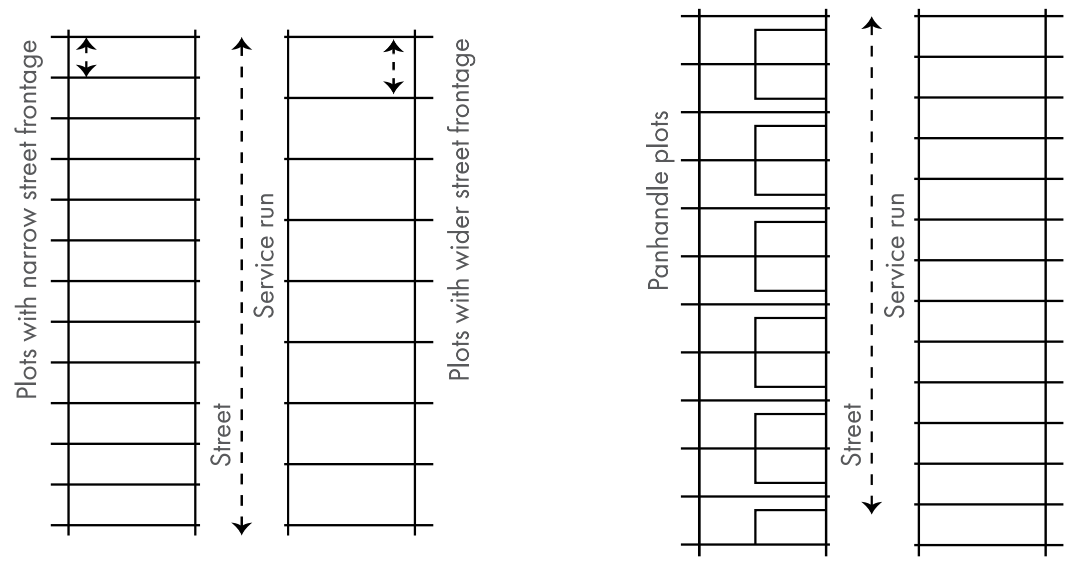


Figure F.22: Plots with narrow street frontages (L) and panhandle plots (R) reduce service costs per plot

F.4.2.4 Densities

The dimensions of street blocks and the subdivision and size of plots have a direct bearing on dwelling and population densities and thus on the optimum use of land. Densification is often associated with positive outcomes such as improving the viability of public transport systems, reducing the per capita cost of providing engineering infrastructure, and allowing for more effective and efficient provision of social facilities. However, higher densities may also have undesirable effects or unintended consequences such as reducing privacy, increasing opportunities for crime, and negatively affecting the character of a neighbourhood. It is therefore important to consider the densities that might result from the street layout and structure of a neighbourhood during the planning and design phase. The link between different housing types and different densities is discussed in Section H.3.3.

When deciding on appropriate dwelling, occupancy and population densities to be accommodated in a layout, the following should be considered:

- Densities are linked to a neighbourhood's character. Neighbourhood character is, among others, determined by architecture, activity and movement, building patterns, scale height and mix of land use. The potential impact of higher densities on existing natural, built and community qualities should be carefully assessed (see Section F.3.2 and Section F.4.7) to find ways to protect these qualities while responding to the future needs of the neighbourhood.
- There is a relationship between densities and the design of buildings. To accommodate more people on a plot (increase occupation and population density), it may be necessary to increase the height of buildings, or open spaces around buildings may have to be reduced. The relationship between residential densities and different types of housing is discussed in Section H.3.3.
- Densities have an impact on traffic volumes. More people living in a neighbourhood would result in higher traffic volumes, both motorised and non-motorised. To ensure that streets remain safe and comfortable to use, modes of transport that are less space-intensive such as NMT and public transport should be prioritised.
- Population and occupancy densities have an impact on open space requirements in a neighbourhood. If these densities are relatively high, residents rely on public open spaces as places for relaxation, recreation and

socialising (see **Section F.4.6** and **Section G**). Access to attractive, safe and comfortable public open spaces therefore becomes important.

- Densities have an impact on social facility provision. Relatively high population densities may improve the effectiveness and efficiency of social facility provision, but larger plots may be required for social facilities to serve the increased total population in the area (see **Section F.4.5** and **Section H**).

Density measurement

Density can be measured in different ways.

- **Dwelling density:** The number of dwelling units (du) per hectare (ha).
  Factors that affect dwelling density are plot size, dwellings per plot and dwelling type, especially the shape, height and configuration (e.g. multiple residential units) of buildings. The dwelling density of an area could be expressed as either gross or net dwelling density.
  - **Gross dwelling density:** the number of dwelling units divided by the total site area.
    Gross dwelling density can be increased by decreasing the size of residential units, decreasing the size of plots or increasing the height and coverage of buildings. An increase in gross density is limited by social facility and open-space requirements – more people in an area need more social facilities and open spaces, which take up more space, thereby lowering gross dwelling density.
  - **Net dwelling density:** the number of dwelling units divided by the area of the site taken up by residential buildings, without consideration of social facilities, open spaces or other non-residential uses. It may, however, include local access streets.
    Net dwelling density will always be higher than gross dwelling density and can be increased by decreasing the size of residential units, decreasing the size of plots, or increasing the height and coverage of buildings.
- **Occupancy density:** The number of people per unit.
  Factors that affect occupancy density are income, the cost of floor space, building design and the need for space in terms of household size.
- **Population density:** The number of people per hectare (the number of people divided by the site area).
  Population density is linked to dwelling density and to occupancy density. It can be expressed as either gross or net density.
  - **Gross population density:** the number of people per hectare on the total site area.
  - **Net population density:** the number of people per hectare of the area taken up by residential plots.

An aspect that also plays a role when determining densities is known as **Floor Area Ratio (FAR)**. It refers to the relationship between the floor area of all buildings (including all storeys) and the total area of the plot. The ratio is used by municipalities as a factor that determines the maximum floor area allowable on a particular site in terms of a land use scheme. To calculate the gross floor area of the buildings allowable on a plot, the area of the plot to be developed must be multiplied by the prescribed ratio. For example, if the FAR on a 1000 m^2 property is set at 0.5, it will translate into a developable gross floor area of 500 m^2.

For a more extensive discussion of density in the South African context, see *Sustainable medium-density housing. A resource book*[49] prepared by the Development Action Group (DAG).

There are no absolute standards for density, and appropriate densities are specific to a range of social, economic and environmental factors. In South Africa, the description of low, medium and high dwelling densities vary, but the following ranges are often used:

- Low density: less than 40 du/ha (gross)
- Medium density: 40 - 100 du/ha (gross)
- High density: more than 100 du/ha (gross)

Densities cannot be easily controlled over time, since they are a result of supply and demand. A layout planned for lower densities may over time absorb more people as a result of the subdivision of large plots and the building of additional accommodation on existing plots, or because more people than anticipated occupy the dwellings in the neighbourhood. It is important that the possibility of densification over time be anticipated and allowed for in the planning and design of a neighbourhood where appropriate.

F.4.3 Engineering infrastructure

Engineering services include water provision, sewage removal, stormwater disposal, solid waste removal, ICT and electricity supply. These services are provided using a range of infrastructure, all of which have different cost implications and environmental and design requirements. Guidance on the provision of the engineering infrastructure is provided in further sections of this Guide. Certain factors should be kept in mind when planning the neighbourhood layout and structure.

F.4.3.1 Integration of engineering infrastructure and layout design

Infrastructure investments should be coordinated and integrated with the layout of a neighbourhood. Consider doing the following:

- Determine the presence, capacity and location of existing bulk or other engineering infrastructure in the area surrounding a development site. The number of connection points will affect the layout of the streets, blocks and plots.
- Design plots with narrow street frontages if possible. The overall cost for infrastructure provided along any given street stays more or less the same, regardless of the number of plots serviced along the street. Therefore, the narrower the street frontage of the plots, the more dwelling units share in the cost of the infrastructure and the lower the infrastructure cost per dwelling unit.
- Minimise the need for pump stations, manholes and junctions as these all have cost implications.
- Keep street block lengths as straight as possible, as any change in direction of the infrastructure requires an additional manhole to be added.
- Keep the road reserves as narrow as possible and widen them at key points to accommodate bus stops, informal trade and other uses.
- Ensure that the road reserve is wide enough to allow access for the maintenance of engineering infrastructure without having to run the risk of damage to adjacent properties or other infrastructure.
- Make adequate provision for larger infrastructure components such as transformer stations, electrical substations and pump stations. Provide separate plots and zone them for utility services or allow space in the layout where these components can be located.
- Consider the solid waste collection methods to be used in the new development and allow, where necessary, for separate plots for appropriate solid waste management facilities (refer to Section M.4.4) and extra space in the layout (e.g. for carts pushed by waste collectors).

The provision of engineering infrastructure on very flat and very hilly sites can be costly. This is particularly true for stormwater infrastructure, and thus those responsible for designing the street layout should work closely with the team dealing with stormwater management. (See **Section L**.)

F.4.3.2 Reticulated services and layout

Service reticulation influences the subdivision of a block into individual plots. Engineering services such as sewage removal, water supply, electrification and telecommunication cabling can be provided through reticulation either in the middle of the block or in the road reserve. Mid-block reticulation is for cost reasons often favoured in low-income areas. By not having to contend with traffic loads and other service infrastructure in the road reserve, service infrastructure located in the middle of a block can usually be laid at shallower depths.

However, there are some difficulties associated with mid-block reticulation. Gaining access to the infrastructure in the middle of a block for maintenance and other reasons is often problematic. Second dwelling units that are constructed to the rear of plots are sometimes built over the mid-block infrastructure, which may not only obstruct access – the weight of the structure on the infrastructure may also cause damage. Municipalities may have specific requirements and local restrictions may apply. (See **Section K.4.4**.)

F.4.3.3 Emergency and service vehicle access

Adequate access for emergency services and service vehicles is critical to serve communities. Street width affects the ability of emergency service vehicles to quickly reach a fire or medical emergency. Neighbourhood street layout must also take the movement of solid waste collection vehicles into consideration, both in terms of loading and manoeuvrability. These collection vehicles should not be required to reverse for more than 12 m if at all possible and they are usually not able to reverse up or down a slope or ramp. Narrow gates or archways and narrow or low-water bridges also restrict the movement of waste collection vehicles. (See **Section M.4.2**.) When designing a layout, consider the following with respect to service vehicles:

- As far as is practical, ensure that service vehicles can travel forward rather than having to reverse.
- Limit the steepness of roads to enable emergency and service vehicle access. (See **Section I.4.6.2**.)
- Provide turnaround facilities for service vehicles in areas with no through-roads (e.g. cul-de-sacs).[50]
- Create space within the layout for refuse collection points where vehicular access is limited.

Layout design for fire safety

Settlement planning and design has limited influence on reducing the incidence of fire, but it can significantly affect its subsequent spread, people's ability to escape from the fire, and the fighting of the fire.

The *National Building Regulations, SANS 10400:2011 Part T: Fire Protection*, deals with fire safety in buildings. These regulations are usually adhered to in formal developments, but they are not always applied in informal settlements. Informal structures generally do not provide the levels of fire protection required, and the lack of adequate open space between dwellings increases the risk of fires having devastating effects in these communities. It is critical for the layout of an informal settlement to allow for access by fire-fighting vehicles and equipment. Consider the following:

- **Ensure adequate space between groups of buildings to limit the spread of fire, to provide escape and to provide access for fire-fighting equipment**
  Ensure there are fire breaks between groups of units, which can be hard or soft open spaces or movement networks. The amount of space is dependent on local weather and the topography. In windswept, flat areas, more space is required and open spaces should be downwind of the prevailing wind direction.

  Heavy fire-fighting tanker vehicles can move only along paved surfaces, but usually have fire-fighting teams that are capable of handling 90 m of hose. Smaller-terrain vehicles carry less water and have 30 m hoses, but they can negotiate unpaved surfaces (gravel roads or well-maintained and clear hard or soft open spaces, including servitudes). Where regularly spaced fire hydrants are not provided, maintained or protected, each building should be within
  - 30 m of a gravel road or a maintained open space network which is linked to the road network at some point, or
  - 90 m of a paved road.

- **Ensure adequate space between individual buildings to reduce the spread of fire**
  Buildings should be grouped together. If dwellings are in groups of 20 or less, this effectively means that the spread of the fire is limited to 20 units at a time, and the safety distance between the buildings can be reduced.
  Decisions regarding plot size and arrangement, and the relationship between plot size, coverage and housing type should take into consideration minimum safety distance guidelines. Minimum safety distance guidelines set in SANS 10400:2011 require a safety distance of 4.5 m from wall to boundary or 9 m between buildings. Where dwelling units are in groups of less than 20 units, this can be reduced to 2 m from wall to boundary or 4 m between buildings.

- **Provide access to water**
  The provision of water for fire fighting is discussed in Section J.4.5.8.

F.4.4 Land use

Approaches to settlement development in the past typically emphasised land use segregation. A more appropriate approach is to integrate land uses in a network of interconnected streets designed for all users to support the development of liveable neighbourhoods. Ideally, the layout of a neighbourhood should allow for a level of land use flexibility, so as to allow land use to adapt to changing movement patterns. For settlements to be flexible over time, the layout must be able to accommodate mixed and changing land uses. A mix of uses has benefits for residents and users of a new development. Where appropriate, and where the size allows, new developments should incorporate a mix of uses. To identify the most appropriate location for certain land uses, certain factors should be considered.

F.4.4.1 Linkages to surrounding land uses

When deciding on appropriate land use for a development, it is important to acknowledge and respond to land uses in surrounding neighbourhoods. Higher-density land uses should be coordinated with those in adjacent neighbourhoods to create a larger centre of activity accessible to both neighbourhoods.

F.4.4.2 Linkages between different land uses

- Place compatible land uses next to each other.
- Create buffers between zones of incompatible uses or between residential areas and risky areas that are prone to natural disasters. The development of parks and recreation facilities in risky buffer areas is appropriate, rather than having areas of poorly maintained or unutilised spaces.
- Create noise buffers where needed (e.g. next to arterial routes, railways or industries) by the positioning of non-residential uses to provide a shield to residential uses.
- Co-locate complementary land uses such as public open space and certain social facilities.
- Allow some residential plots to be used for small industry or small-scale businesses.

F.4.4.3 Nodes and streets of activity

A layout should provide for a mix of land uses and access to an identifiable activity area (node or street). This activity area provides goods and services to meet residents' daily needs and provide important gathering places for the community. If activity areas already exist in the neighbourhood, easy access should be provided to link any new development. Should it be necessary to plan for activity nodes or streets in the layout of a new development, the following should be considered:

- Designate activity nodes or streets in locations where activity is already concentrated.
- Locate appropriate and supportive land uses, such as mixed-use and higher-density developments, along public transport routes.
- Place social facilities in highly visible and accessible locations. Public squares can be used to emphasise the civic status of these social facilities.
- Enable and encourage formal and informal (where appropriate) retail or other commercial land uses in the activity zones.
- Locate higher-density housing close to identified activity nodes and along designated activity streets. Show the distribution of higher-, medium- and lower-density residential areas in the layout plan.

F.4.4.4 Land use and transportation linkages

The existing and planned public transport system provides the opportunity to concentrate development, affect the settlement's form, and conserve the existing character of established neighbourhoods. To link land use and transportation in a layout, the following is suggested:

- Locate land uses or activities that generate a large volume of traffic along or near a main road that can be easily accessed by public transport.
- Create TOD nodes or zones at major crossings. These nodes should be served by public transport and should have high walkability.
- Locate non-residential and higher-density residential uses closer to main public transport routes (Figure F.23).

Figure F.23: Locate higher-density development along public transport routes

Mixed-use developments

Mixed-use developments are created by combining a range of compatible land uses into a single neighbourhood. Rather than merely consisting of a residential component, these neighbourhoods allow people to live, work, play and shop in the same area. Such developments also allow for the provision of a range of housing types (see Section H.3.3.2), which could accommodate a mix of tenure options, income groups, and social and age groups. Mixed-use developments usually result in a medium (dwelling and population) density area (see Section F.4.2.4) and provide opportunities to create a walkable neighbourhood (see Section F.4.2.2).

Potential benefits to residents of a mixed-use development may include shorter travel times, lower transportation costs, the increased viability of home-based enterprises and greater opportunities for social interaction. Community benefits of this type of development may include lower infrastructure costs and more efficient use of space and social facilities.

When designing the layout and structure of a mixed development, the following should be considered:

- Consult with the local municipality about the proposed zoning for a development. Some municipalities already have zoning categories that allow for a mix of land uses, while others have 'special' zoning categories with specific requirements.
- Locate higher-density uses near the entrance to a new mixed-use development site to minimise the length of roadways and of reticulated engineering services.
- Locate higher-densities and a horizontal mix of uses along major streets, in nodes and next to green open spaces.
- Locate compatible uses and building types near the mixed-use development's edge to serve as a buffer with adjacent areas of lower density.

See Section H.4.1 for more guidance on the clustering of different facilities and land uses.

F.4.5 Social facilities

The provision of social facilities is planned at provincial, regional or local level. This section deals with the relationship between street layout and the provision of social facilities. More details regarding the planning and design of social facilities are provided in Section H.

Social facilities are critical to the functioning of any settlement and should be considered from the outset when planning and designing the layout of a neighbourhood. The placing of social facilities within neighbourhoods affects diverse aspects such as movement patterns and land use choices and could potentially contribute to better functioning and more equitable neighbourhoods.

After having applied the guidelines set out in Section H and having determined the number and size of facilities to provide for in the development project, the following need to be considered when planning for social facilities in a layout design:

- Assess the provision and viability of facilities in relation to the location and scale of the development project. Often it may not be necessary to provide certain facilities because they are already available in neighbouring areas and can also provide services to the residents of the new development. It is however not socially responsible to rely only on neighbouring areas for services, as inevitably the cumulative impact of a number of new neighbourhoods will have an impact on local services. Where possible, a number of neighbourhoods should be planned together so that each contributes equitably to the provision of land or facilities for social service provision.

- Group and develop social facilities as clusters or civic precincts according to their function so as to facilitate the sharing of resources and utilities between facilities (see Section H.4.1 for guidance on how different facilities could be grouped). Social facilities could also be clustered with retail or other commercial land uses to support nodal development and facilitate user access and convenience. When designing the layout, the following should be done to make provision for clustered social facilities:
    - Set aside relatively large plots for social facility clusters or civic precincts that are well located relative to existing or future public transport. These plots could be subdivided at a later stage if necessary.
    - Combine social facilities with hard public open spaces in order to accommodate supporting activities such as trading.
    - Locate social facilities adjacent to public transport ranks, stops or facilities.
- Provide direct, safe and convenient routes between social facilities and public transport stops, in order to increase inter-neighbourhood access for those who use public transport.
- Provide a pedestrian-friendly network to link social facilities, public open spaces and public transport. See Section F.4.2.2 for a discussion on the walkability of neighbourhoods.
- Place social facilities on plots where they may become a neighbourhood landmark. This will contribute to the character of the neighbourhood and assist people in finding their way.

The specific location of a social facility in a neighbourhood should support the service to be provided. For instance, facilities that typically only serve a particular local community need to be accessible to the local community:

- Locate neighbourhood-focused facilities such as crèches in quiet and safe areas that are accessible to pedestrians.
- Identify social facilities to be placed in a safe geographical location that can be used as refuge in case of a natural disaster such as flooding or torrential rain.

Facilities that serve a broader community, or are likely to outlive the current community usage, should be "externalised" in the sense that they should be located on the edges of the neighbourhood or at places where they can be accessed with relative ease from surrounding neighbourhoods:

- Locate facilities such as clinics, taxi ranks, public service centres, post offices and pay points at a central locality that is accessible to several neighbourhoods to serve the greatest number of people.
- Locate emergency support facilities such as fire stations and police stations at places with easy access to distribution roads.
- Locate social facilities at accessible points on the settlement movement network. This will increase the facilities' catchment areas.

F.4.6 Public open space

Public open space is a key component of any well-functioning settlement. Public open space should from the outset be incorporated into the layout of a development as one of the structuring elements. Provision should be made for community spaces such as playgrounds, neighbourhood parks, green corridors, riparian protection zones and squares for commercial activities like public markets. These spaces play an important role in the improvement of residents' quality of life. They reduce air, sound and visual pollution, protect the soil and the natural water cycle, and improve the permeability of the ground.

The planning and design of different types of public open space, including size and threshold guidelines, is discussed in Section G. However, decisions regarding the provision of public open space should not merely be based on thresholds, percentages or numbers per population. The role that public open space plays in improving the liveability of a neighbourhood should always be acknowledged, but must be balanced against the ability to maintain the space over the long term. The most efficient way in which public open space could be provided and where it should be located should be informed by the context and local conditions. The principles of crime prevention through environmental design as outlined in Section O.1 should also be carefully considered when planning and designing public open space.

F.4.6.1 Networks of public open space

Networks of public open space are often more useful for visual amenity, recreational use and wildlife corridors than isolated and unrelated landscape elements. These networks create linkages to existing urban areas, other development sites and the wider landscape. When planning and designing public open space as part of a neighbourhood layout, consider the following:

- Create a network of hard open spaces including streets, squares and courtyards. The movement network (streets and other routes) should form the basis for the network of hard open spaces. Neighbourhood streets can also serve as public spaces that are used for a variety of social activities (see Section F.4.1).
- Create a network of soft open space by joining up elements such as linear parks, road reserves, sports fields, private gardens, buffer planting and surface drainage corridors.
- Identify possible linkages with existing open space networks in adjacent neighbourhoods.
- Create greenways that run through or along linear neighbourhood elements such as natural streams or wooded belts and connect with parks and footpaths in nearby neighbourhoods. These can then link to neighbourhood streets that have cycle routes.
- Integrate public open space networks with engineering services like major stormwater systems (retention ponds, aquifer recharge areas and open water canals) to enable these spaces to perform numerous functions, thereby creating activity and surveillance.
- Designate areas prone to risk – such as gullies, watercourses and steep hills that are not suitable for building – as part of the natural public open space.
- Create fewer, but larger and more multi-functional public open spaces, rather than many public open spaces that are expensive to manage and maintain.[51]

F.4.6.2 Access to public open space

It is important to ensure that public open spaces are accessible, as residents use public open spaces and natural resources such as rivers and beaches for a variety of purposes, including as sites of worship, for rituals and for initiation practices. To optimise accessibility, consider the following:

- Locate appropriate hard and soft open spaces at points of access, for example at transport mode interchanges, public transport stops, on important access routes and close to active intersections so as to make them as accessible as possible.
- Place local parks (for children's play, etc.) within walking distance of the majority of homes.
- Locate spaces of exchange and interaction in bustling areas.
- Locate spaces of relief and relaxation in quieter areas.

F.4.7 Neighbourhood identity

The layout and structure of a development could contribute to the creation of a neighbourhood with a strong identity. Street layout and the interaction between buildings and open space could play a role in creating a well-functioning neighbourhood with an interesting, pleasant or aesthetically pleasing character. However, if not well considered, the layout and structure could result in a bland neighbourhood with a dull and uninspiring character. This could make for a confusing place, where it is easy to get lost and disoriented. The layout and structure of a development can be used to create places, not only spaces, by doing the following:

- Ensure that the street network is easy to understand and structure the streets and spaces in such a way that it is obvious which streets are the more important ones that connect places and are used by many people, and which are the more private, quieter streets that are mostly used by the people living on them.
- Identify opportunities for creating or reinforcing a sense of identity, for instance by using distinctive landscapes, natural features, buildings, streets, street patterns, spaces, skylines or building forms as structuring elements. The layout could be designed to incorporate these as landmarks, vistas and focal points (Figure F.24).

Photo credit: Chris Kirchhoff (R) - www.brandsouthafrica.com

Figure F.24: Identify opportunities for creating or reinforcing a sense of identity

- Use the most important transport interchanges or nodes to serve as gateways to the neighbourhood.
- The way buildings are placed on a plot and the relationship between buildings and the street (Figure F.25) have an impact on how users perceive and experience a neighbourhood and therefore also contribute to the neighbourhood identity (refer to Section H.4.2).

Figure F.25: Sterile street due to boundary wall (T); interaction between building and street without wall (B)

Glossary, acronyms, abbreviations

Glossary

Building line
An imaginary line that defines an area within and parallel to the boundary of a plot within which no permanent structures may be built. The purpose of the building line is to prevent buildings from being erected too close to neighbouring properties or to the street. Building lines are defined in the local land use scheme and are not the same for all plots.

Consent use
Consent use means that a municipality allows additional land use rights on a particular property upon request. The zoning of the property will not be changed. The zoning category, as described in the land use scheme, usually makes provision for a pre-described number of uses that may be allowed for with the necessary consent.

Coverage
The footprint area of a building expressed as a percentage of the total plot area, as seen from directly above the property. The coverage is not affected by the number of storeys of the building. For example, a building with an area of 400 m^2, which is located on a plot of 1 000 m^2, will have a coverage of 40%.[52]

Desire line
An imaginary line that links facilities or places, and that would form a convenient and direct route for pedestrians and cyclists. Desire lines become evident when watching people move through an area. These lines are often visible as informal footpaths across an open space.

Grain
Grain or urban grain refers to the pattern and intensity of buildings and their plots, as well as how they combine to form blocks within a settlement. Grain may be 'fine', comprising small blocks and frequent street junctions, or it may be 'coarse', comprising large blocks and infrequent street junctions.

Land use scheme
A land use scheme forms part of a land use management system that regulates and manages land use within a municipality. The scheme confers legal rights to properties to develop and to erect and use buildings subject to certain stipulated conditions. A detail description of the content of a land use scheme is provided in Chapter 5 of SPLUMA.

Plot
A measured piece of land, also known as an erf, stand or site that is registered at the deeds registration office or forms part of a municipal land use scheme.

Rezoning
A colloquial description of the process of making an amendment to a land use scheme (or any of its provisions), to change the land use rights and development restrictions applicable to a specific property.[53]

Road reserve
A road reserve is a legally described area within which facilities such as roads, footpaths and associated features

may be constructed for public movement. It is the total area between boundaries shown on a cadastral plan. It may also include an area alongside the road that may in future be used for expansion of the road width.

Sense of place

The sense of place of a neighbourhood can be described as the attitudes and feelings that individuals and groups hold towards the neighbourhood. A sense of place is therefore subjective, but useful generalisations can be made e.g. that some spaces, at least for most people who encounter them, provide an experience that is unique and place-specific rather than generic. Places that have unique characteristics and histories are often considered to have a heightened sense of place. Layers of history, unique architecture or layouts, and place-specific signs and symbols help differentiate one place from another. But sense of place is not just about the physical environment, it also entails our perceptions of the positive social interactions that we partake in and those that we observe within a neighbourhood.[54]

Servitude

A servitude is a registered right that a person or an entity has over the immovable property of another person. It usually means that a portion of land is set aside for a specific purpose, such as road widening, or provision for engineering infrastructure (e.g. water pipelines, electricity cables, sewerage pipes). The municipality might for example have the right to construct electricity cables over a privately owned property. The property owner is then restricted in what he or she can do within the servitude. The servitude is attached to the property and will continue to exist even if ownership of the land changes. The servitude forms part of the conditions contained in the title deed and can only be cancelled by agreement between both parties.

Site development plan

A plan that provides an overview of the intended development on a property, specifically indicating features such as the position of the proposed buildings, access provisions, parking, landscaping, adherence to the building lines and the position of servitudes.

Spatial Development Framework

SPLUMA requires all three spheres of government to produce Spatial Development Frameworks (SDFs). The focus of the three types of SDF differ. The national SDF provides broad strategic direction, provincial SDFs focus on the coordination of spatial development, and a municipal SDF contains detailed plans for the particular area of jurisdiction. Within the municipal sphere, the SDF forms a core component of the Integrated Development Plan (IDP) and guides the overall spatial distribution of current and desirable land uses within a municipality to give effect to the vision, goals and objectives of the municipal IDP. A detailed description of the content of SDFs is provided in Chapter 4 of SPLUMA.

Sprawl

Sprawl is sometimes described as an urban form that is the opposite of the desirable compact city. Sprawling areas are generally known for low densities, decentralised nodes and uniform land uses. However, what is considered to be sprawl can be found along a continuum of more compact to completely dispersed development. A variety of urban forms have been described as 'urban sprawl', including contiguous suburban growth, linear strip developments, leapfrog and scattered developments and extended residential development in tribal authority areas.[55]

Street block

A street block is the smallest part of a settlement enclosed by streets. It is usually rectangular in shape and usually contains several buildings.

Subdivision of land
Land subdivision is the act of dividing a parcel of land into two or more pieces for the purpose, whether immediate or in the future, of selling the land or using it for building development.

Superblock
A superblock is a street block that is much larger than a traditional street block. It is often used in layouts to reduce the impact of cars on a neighbourhood by barring access to motorised traffic while still allowing pedestrian routes through the block.

Title deed
A title deed is a government-issued document that stipulates who the owner of the property is, the property's land use zoning and associated rights, as well as any restrictions such as servitudes, amended building lines, and area-specific conditions.

Township establishment
Township establishment is a legal process whereby agricultural land is converted into proclaimed individual plots (with certain land use rights attached to them) which can be transferred to different owners. The process is regulated by SPLUMA.

Verge
The verge is the area between the roadway edge and the road reserve boundary.

Zoning
A property's zoning stipulates the purpose for which the land may be used and is described in the municipality's land use scheme. The zoning also stipulates restrictions on the building erected on the property in terms of floor area ratio, coverage, density, parking requirements, etc. In order to change the purpose for which the property can be used, an application for rezoning has to be submitted to the local municipality for consideration.

Acronyms and abbreviations

BEPP	Built Environment Performance Plan
CBA	Critical Biodiversity Area
CBD	Central Business District
DAG	Development Action Group
EIA	Environmental Impact Assessment
ESA	Ecological Support Area
FAR	Floor Area Ratio
IDP	Integrated Development Plan
IUDF	Integrated Urban Development Framework
NEMA	National Environmental Management Act
NMT	Non-Motorised Transport
PGDS	Provincial Growth and Development Strategy
SAHRA	South African Heritage Resources Agency

SANBI	South African National Biodiversity Institute
SDF	Spatial Development Framework
SDG	Sustainable Development Goal
SPLUMA	Spatial Planning and Land Use Management Act
TOD	Transport-Oriented Development
WSD	Water Sensitive Design
WSUD	Water Sensitive Urban Design

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Section G
Public open space

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 G
Public open space

The Neighbourhood Planning and Design Guide

Table of contents

G.1 Outline of this section

G.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 public open space in this system. Public open spaces support a broad spectrum of activities and take on various forms. Open space performs important environmental functions and plays a key role in improving the health of communities.

Public open space refers to all publicly or privately owned land that is completely or partially open for use by the public. Some of these spaces may include buildings and other physical structures. The terms 'public open space' and 'open space' are used interchangeably in this Guide.

Public open spaces, along with housing, social facilities and engineering infrastructure, are significant neighbourhood assets that contribute to the creation of liveable and sustainable neighbourhoods. The aspects addressed in this section play an essential role in achieving the vision for human settlements outlined in **Section B**, and they relate in particular to **Section F** (Neighbourhood layout and structure) and **Section H** (Housing and social facilities).

G.1.2 Content and structure

This section (Section G) is structured to support effective decision-making related to the provision of public open space. The decision-making framework is outlined in Figure G.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 public open space 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 public open space 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 public open space that are available for consideration

Design considerations

Guidelines to assist with the design of public open space.

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 G.

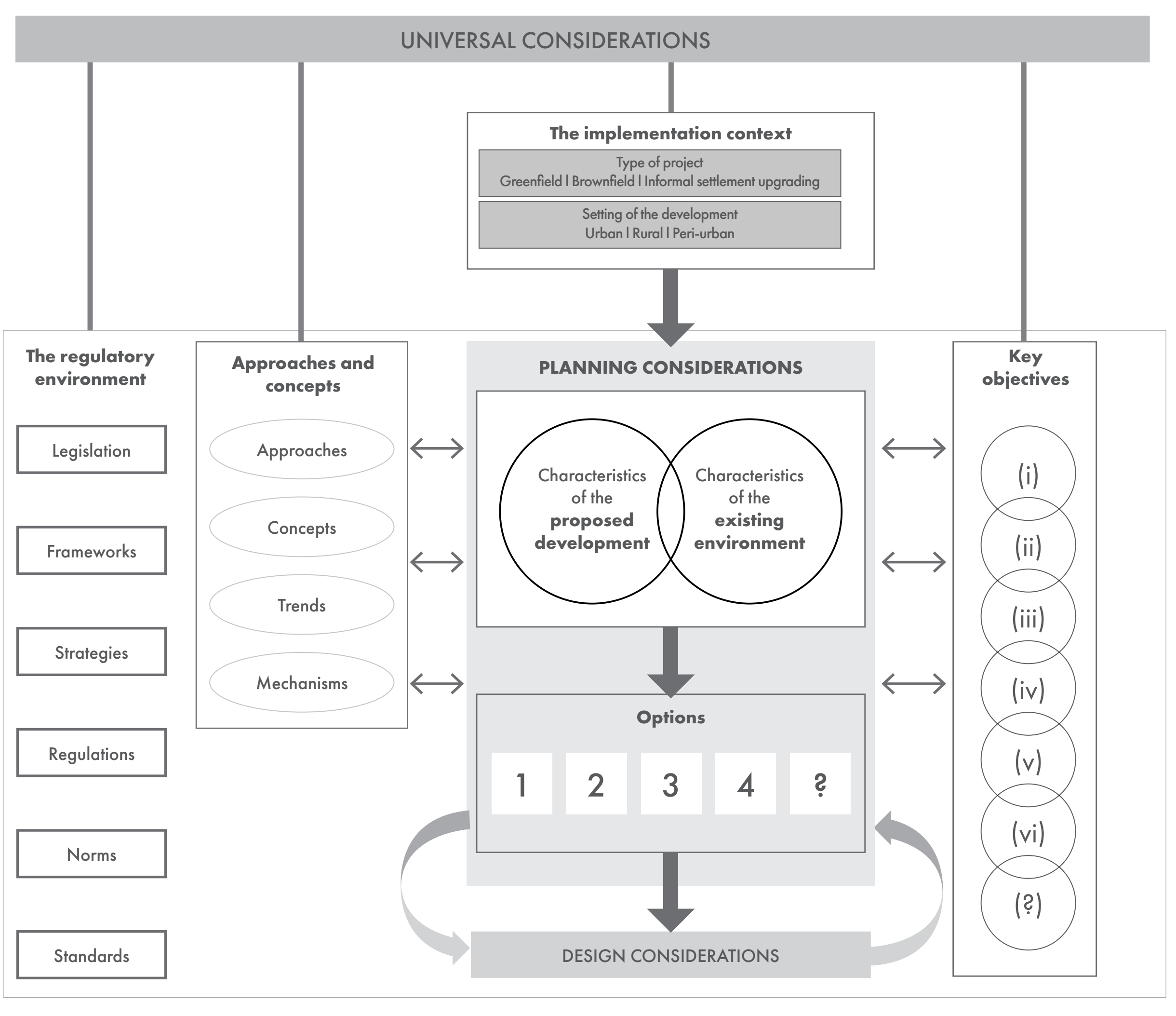

Figure G.1: A framework to assist with planning and design decisions

G.2 Universal considerations

G.2.1 The regulatory environment

The provision of public open spaces is not regulated by a single government department or located within a single sphere (national, provincial or local) of government. Legislation and policy that may have direct implications for open space provision are briefly outlined 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.)

(i) The Spatial Planning and Land Use Management Act, 2013

The Spatial Planning and Land Use Management Act (SPLUMA) is a framework act for all spatial planning and land use management legislation in South Africa. Among others, SPLUMA requires that national, provincial and municipal Spatial Development Frameworks (SDFs) be developed. Development principles, norms and standards as identified in SPLUMA guide all actions relating to spatial planning and the development or use of land, and each municipality has to adopt and approve a single land use scheme for its entire area.

Certain aspects addressed in SPLUMA relate directly to open space provision. Take note of the following requirements:

- Consider the municipal SDF when planning the project to ensure alignment with the SDF.
- Consider the municipal SDF when planning the project to understand the context of the project as depicted in the municipal SDF. Typical questions to ask include: What land use and densities are planned in the vicinity of the project? How will the project relate to the proposed developments in the rest of the municipal area?
- Adhere to the development principles (outlined in SPLUMA), namely spatial justice, spatial sustainability, efficiency, spatial resilience and good administration.
- Observe the regulations contained in the municipality's land use scheme regarding the use and development of land; the use, size and scale of buildings; and the intensity or density of land use.
- Adhere to the conditions of title as set out in the title deed of each property.
- If required, apply to the municipal planning tribunal to change the use, form or function of land; or remove, amend or suspend a restrictive condition.

(ii) National Environmental Management Act, 1998 (and its subsequent amendments)

The National Environmental Management Act (NEMA) 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. A distinction is made between Listing Notices 1 and 3 activities, which require a Basic Assessment, and Listing Notice 2 activities, which require a full EIA (scoping followed by impact assessment). The latter involves a systematic and comprehensive process through which detailed information is gathered on the social, economic and environmental consequences of proposed developments. The environmental authority uses this information to decide whether development applications will be approved. NEMA also introduced the development of Environmental Management Plans, which most municipalities are considering or requiring when compiling SDFs. Other acts that support environmental management at a national level include the following:

- The National Environmental Management: Protected Areas Act, 2003
- The National Environmental Management: Air Quality Act, 2004
- The National Environmental Management: Biodiversity Act, 2004
- The National Environmental Management: Integrated Coastal Management Act, 2008

Certain aspects addressed in NEMA relate directly to the provision of public open space. For instance, open space should be planned and designed in accordance with the environmental management principles contained in NEMA. Furthermore, the national register of all national, provincial and local protected areas should be consulted to determine their proximity to and possible impact on the project site.

Any intervention along a watercourse is subject to national legislation. The National Water Act, 1998 should be consulted in this regard and depending on the characteristics of the site and type of work being done, NEMA and its associated acts should also be considered.

(iii) National Heritage Resources Act, 1999

The National Heritage Resources act introduces an integrated and interactive system for the management of national heritage resources. According to the act, heritage sites, protected areas and heritage areas need to be taken into consideration when developments are planned (see Section F.3.2.1. (v)).

(iv) National, provincial and local policies, frameworks and guideline documents

For the planning and design of neighbourhood public open space, the domain-specific guidelines, policy, norms, standards and regulations of a number of relevant government departments (e.g. Public Works, Environmental Affairs, Water and Sanitation, and Rural Development and Land Reform) or entities (e.g. the South African National Biodiversity Institute (SANBI)) should be consulted. Several national government departments have guidelines aimed at the local level, such as the Department of Rural Development and Land Reform's *Draft Guidelines for the Provision of Open Space*[1] and the National Treasury's Urban Network Strategy toolkit.

At a local level, the planning mechanisms employed by municipalities need to be considered, including Integrated Development Plans (IDPs), Spatial Development Frameworks (SDFs), environmental management frameworks, land use schemes, green by-laws and dedicated open space guidelines.

It is important to take into consideration all goals, principles, spatial implications and guidelines contained in these documents when planning and designing the provision of open space.

G.2.2 Key objectives

Positively performing neighbourhoods – those that are generally regarded as successful and liveable – tend to have certain characteristics in common. These characteristics could be translated into a set of objectives to consider when decisions are made regarding the planning and design of public open space. A number of objectives should guide decisions regarding the planning and design of open space.

(i) Conserve and protect the natural environment

Neighbourhoods should contribute to stabilising global greenhouse gas (GHG) concentrations in the atmosphere and to protecting people from the impacts of climate change (see **Section B.2**). Neighbourhoods are dependent on healthy, functioning ecosystems to contribute to the creation of green, climate-safe settlements. Therefore, public open space should be planned and designed to enable ecological processes to occur sustainably and safely within environments that have been altered by human intervention. It is important that the ecological integrity of especially green open spaces, whether natural or cultivated, be maintained through careful stewardship, the protection of biodiversity, and by minimising waste. Where the disturbance of ecosystems cannot be avoided, the negative impact on the environment should be minimised.

(ii) Assimilate public open space into the surrounding neighbourhood

Public open space should be integrated into the neighbourhood and also into the broader settlement structure. The location of open space and its contribution to the layout and structuring of neighbourhoods are discussed in **Section F.4.6**. Public open space could be assimilated into the neighbourhood by considering the following:

- Public open space should be compatible with adjacent land uses. Each open space type (see **Section G.3.3**) will have different requirements for compatibility. For instance, a playground should preferably not be located next to a busy road, or, if this cannot be avoided, it should be planned and designed in such a way that the safety of the users of the playground is ensured.
- Public open space should be clearly demarcated. Demarcation does not necessarily mean that an open space should be fenced in or that some other form of physical barrier should be constructed along its perimeter. A change in land use could be indicated by various means, including a change in the surface treatment or by using vegetation to define the edge of the open space. Clearly defined open space that relates to the surrounding area in a welcoming way is usually better used. Blurred edges can result in confusion regarding management responsibilities of the space.

(iii) Promote accessibility for all

Public open space should be accessible to all residents of a neighbourhood. Where possible, these open spaces should be accessible by non-motorised transportation (NMT). In the case of certain types of public open space (e.g. regional parks or big sports complexes), close proximity to the existing public transport network is essential. People, whether disabled or not, should be able to use public open spaces comfortably and safely and, as far as possible, without special assistance. This accessibility requires a wide range of design interventions such as tactile paving, accessible toilet facilities, ramps, dropped kerbs and handrails (see **Section O.2**).

(iv) Respond to users' needs

Open space should respond to users' needs and requirements. Some needs are common to all user groups, while specific requirements could be ascribed to certain user groups, for instance young children who need secure play areas with good surveillance. Traders might need shelter and lock-up facilities. Spaces should be designed to create places that are 'fit-for-purpose' and useable. Needs may differ between the users of the various open space types, but common needs include the following:

- All users require a degree of comfort and protection from the natural elements, such as either a shady or a sunny place to rest.
- All users need to feel safe from crime. The design of public open space should aim to reduce the actual and perceived levels of crime and violence (see Section O.1).
- All users require spaces that do not pose a health risk or expose them to dangerous vehicular traffic.
- The design of open space should support easy maintenance of facilities and efficient waste management.

G.2.3 Approaches and concepts

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

G.2.3.1 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.[2] 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.[3] 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 G.2.)

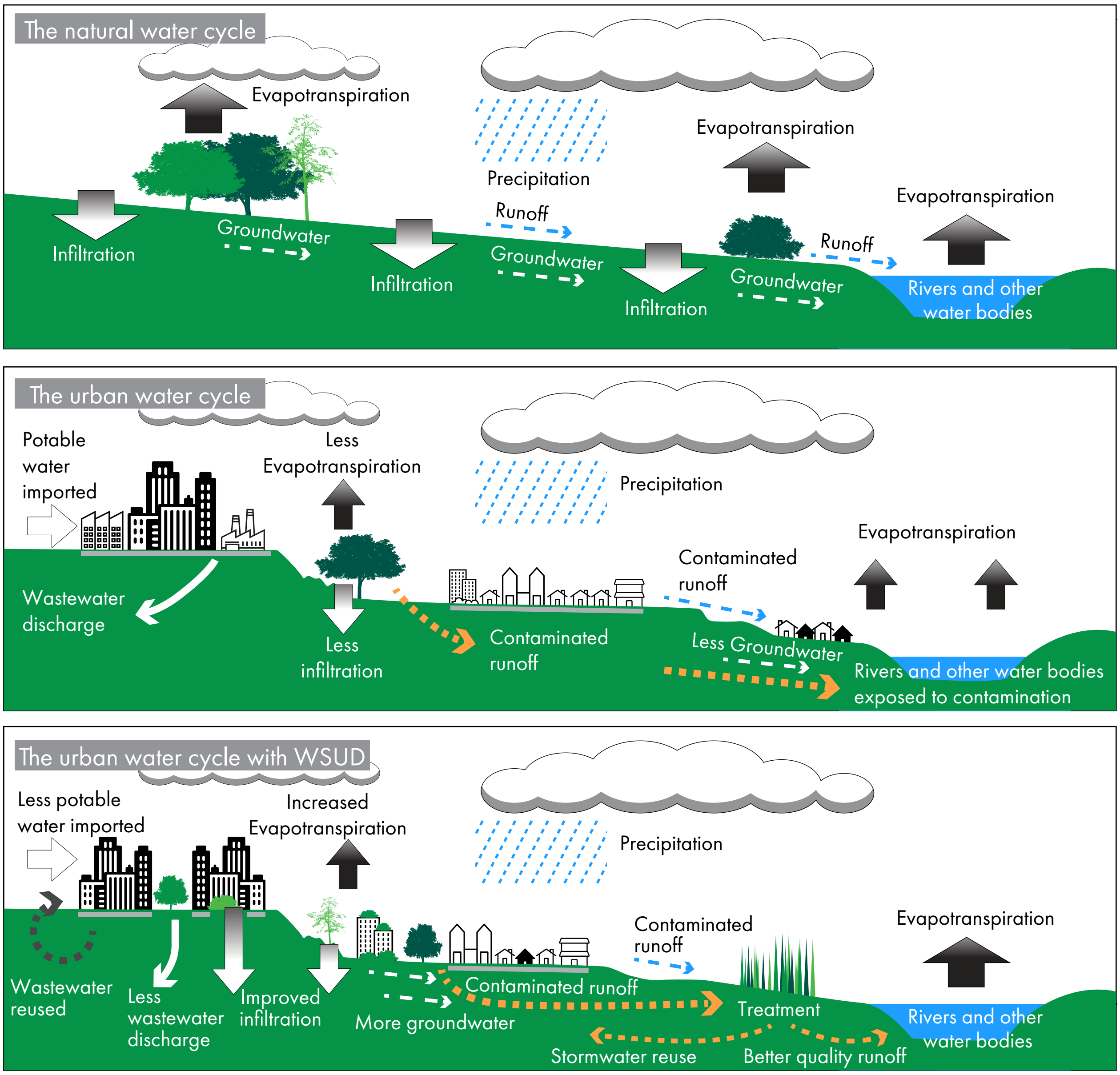

Figure G.2: The water cycle under different conditions

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 water and to create settlements that preserve the natural water cycle. Strategies or interventions that could be implemented include the following:[4]

- **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.[5]
- **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 J (Water supply), Section K (Sanitation), and Section L (Stormwater).

G.2.3.2 The street as open space

While movement remains the determining factor in the design of neighbourhood streets, these hard (paved) open spaces are also vital places where people interact, socialise and experience the neighbourhood. Pedestrian-oriented streets are streets specifically designed to prioritise pedestrians, such as 'woonerf' streets and arcades. Variations on the concept include streets that are closed (temporarily or permanently) and alleys or cul-de-sacs that are used for trading, markets, recreation and entertainment. Two of these concepts (woonerf and open streets) are briefly described below.

A woonerf is a type of street or group of streets that function as shared public space – for pedestrians (specifically children), cyclists and slow-moving cars. Originating in the Netherlands, the woonerf is often designed without traffic lights, stop signs, different lanes or even sidewalks, as the focus is on encouraging human interaction – those who use the space are forced to be aware of other users, make eye contact and anticipate actions. The woonerf gives NMT absolute right of way and requires motorised vehicles to drive at a walking speed. By requiring cars to drive slowly, the street is converted into an open space that can be used for a range of activities, including play, trade and exercise. The woonerf is mostly used in residential areas and the design often caters for attached or semi-detached housing that faces onto the pedestrian-oriented street. The woonerf concept is linked to the superblock street layout as discussed in Section F.3.3.1.

Photo credit: Ference Isaacs (R)

Figure G.3: Typical layout of a woonerf (L); a street closed off temporarily for community activities (R)

The citizen-driven initiative of 'open streets' (which originated in Bogota, Colombia) attempts to change how people use, perceive and experience streets. By temporarily closing off streets to motor vehicles, the open streets become public open spaces for a few hours or a day (often once a week or once a month). People, including pedestrians, runners, traders, skaters, and cyclists can use the space as they like. This temporary form of public open space can potentially add to the liveability of neighbourhoods by creating safe opportunities for interaction, trading and exercise.

G.2.4 The implementation context

This section highlights the contextual factors (specifically related to the type of development and its setting) that should be considered when making decisions regarding the provision of public open space. Also refer to **Section D.2.1** (Type of development) and **Section D.2.2** (The setting of the planned development).

G.2.4.1 The type of development

(i) Greenfield development

The location of open spaces on a greenfield site can be used as a structuring mechanism for neighbourhood layout. Certain areas of a greenfield site may include functioning ecosystems such as ridges, rivers, wetlands or areas worth conserving, and can then be accommodated in the neighbourhood layout from the outset. Within a greenfield development, the type of public open space will further be influenced by the needs of the anticipated residents, as well as the availability of open space in the adjacent neighbourhoods and the remainder of the settlement.

(ii) Brownfield development

Brownfield sites, by their nature, have limited space available for development, and allocating or retaining land for public open space is often a challenge. Existing open spaces (if retained) can be redesigned to respond better to the needs of the new (often higher-density) development. New open spaces can potentially be established on sites that were used for something else in the past, for example by converting parking areas into a different type of open space, by establishing rooftop gardens, by rezoning road reserves (that are not used) and by rehabilitating unused landfill sites and transforming them into useful open space.

(iii) Informal settlement upgrading

Population densities in informal settlements are often relatively high, which means that the provision of public open space needs to be considered carefully. Dwellings (shacks) in informal settlements are usually relatively small and residents are often forced to use the public realm for a variety of everyday activities, including socialising, playing and doing laundry. Appropriate public open spaces should therefore be provided when such settlements are upgraded. If parts of an informal settlement are located on land unsuitable for development (e.g. areas within a floodline), it may sometimes be possible to utilise such land as public open space.

G.2.4.2 The setting of the development

(i) Urban

The urban areas of South Africa comprise a variety of settlement types. As urban areas have higher population densities and many people, the provision and design of appropriate public open space become critical. The open space to be included in an inner-city development will differ from that required in, for instance, a suburban setting. In an urban setting, due to shorter distances and more users, the relationship between different spaces is as important as the space itself.

(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. Given the transitional nature of peri-urban areas, the nature of developments will vary considerably, and so will the type of open space to be provided.

(iii) Rural

Rural areas in South Africa comprise a variety of settlement types, including rural villages and towns, dense rural settlements and dispersed settlements. Development sites in rural areas will vary in nature depending on the location – for instance whether it is situated in a rural town or in a dispersed settlement. The type of public open space appropriate to the setting will therefore also vary. Due to the abundance of open space in many rural settlements, the open spaces in rural areas are often not focused on passive recreation (e.g. relaxation, walking, 'people watching'), but more on active recreation (e.g. sports fields and play areas for children). In some cases, the open space may be influenced by cultural considerations, the ownership of the land and tenure arrangements (for instance if it is managed by traditional leadership).

G.3 Planning considerations

This section deals with the planning of the provision of public open space. In this context, the term 'planning' means making informed decisions regarding the type of open space to be provided, based on a thorough understanding of the context within which the planned open space will be provided.

The decisions regarding public open space provision 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.

This section outlines a range of questions that need to be asked and factors that have to be considered before deciding on the type of open space to be provided, and before the open space infrastructure can be designed.

G.3.1 Characteristics of the proposed development

Decisions regarding public open space provision 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.

G.3.1.1 The nature of the proposed development

The nature of the development that is planned will influence decisions regarding the provision of public open space. For instance, the provision of open space might not be necessary as part of a small development project, as residents' needs might be met by existing open space in surrounding neighbourhoods. Large (or mega) projects may have to include a range of open space types. The nature of a project therefore needs to be understood to make informed decisions regarding public open space provision. The following questions can be asked to gain clarity:

- What is the dominant land use of the proposed development? What supporting land uses will be present?
- What social facilities are planned? These facilities can often be clustered with other public facilities and located adjacent to public open spaces (e.g. squares, transport facilities or parks) to create service precincts.
- If a mixed-use development is proposed, what type of mix is proposed, e.g. a variety of housing types, sizes, densities and/or tenures? (See **Section F.4.4** for a discussion of mixed-use developments.) The open space requirements of mixed-use projects will differ from projects that are primarily residential in nature.

G.3.1.2 The residents of the area to be developed

Decisions about public open space provision need to be guided by information regarding the potential residents and users of the planned open spaces. Usually, the identities of the actual occupants of the houses to be provided are not known when a residential development is planned and designed. It may be possible to make assumptions regarding the profile of the future residents and users of open space by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to establish the following:

- The total number of residents that would have to be accommodated. Actual numbers may be higher than anticipated due to the fact that the provision of houses and services may attract more people than originally planned for.
- The number of households, the range of household sizes and the types of housing to be provided in the development. This will have an impact on the type and number of public open spaces to be provided.
- The composition of the potential user groups in terms of age, gender, income and levels of mobility. Young families, for example, need playgrounds for pre-schoolers. Public open space should, as far as possible, be accessible to all residents and users, whether they are disabled or not.

G.3.2 Characteristics of the existing environment

Decisions regarding open space planning and design 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.

G.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the development site could influence the planning and design of public open space. The physical characteristics of a site will influence the type of land use, buildings and activities that could potentially be accommodated within the open space.

(i) Landscape and ecology

The physical features of the landscape should have a substantial impact on the planning and design of open space, as (soft) open spaces perform ecological functions within a neighbourhood. These functions may include drainage, aquifer recharge, air and water purification, or maintaining biodiversity. Some open spaces are established to protect ecologically sensitive areas (e.g. nature reserves), while other open spaces may be developed on sites that are not suitable for conventional construction (e.g. some dolomitic areas).

A thorough analysis of the landscape and ecology should be conducted to determine the location and nature of all ecologically sensitive areas. Such an analysis will assist with site planning and influence the positioning (and ease of construction) of possible infrastructure and buildings. 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:

- 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).[6]
- Endangered or protected plant or animal 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 position of any telephone poles, overhead or underground power cables, rock outcrops, water features, dongas, etc. that could restrict building work or may require involvement (especially permission) from various government departments

(ii) Topography

The topography will be a key factor in the site layout and where possible buildings should be placed. It will also affect the views to and from the open space and the provision of engineering services. The following questions will assist in highlighting pertinent issues:

- Does the site slope? Are there significant changes in level, such as embankments or retaining walls? Gradients have an impact on the provision of facilities for pedestrians, cyclists and other types of NMT (see **Section I**). They also affect access for people with disabilities (see **Section O.2**).
- Can the development be oriented to make the most of attractive views?

(iii) Climate

The micro- and macro-climates of the site will influence the placing of facilities within the open space. The following questions need to be asked:

- Is the site exposed to prevailing winds? Is the wind direction seasonal? This information would assist in positioning and orientating (for instance) squares so that they are protected from the wind.
- Where does the sun rise and set in summer and winter? The availability of shade may be important to the users of the open space. Remember there may be external features that influence sun penetration on the site, such as a nearby mountain, hill, tree, or building.
- Does the site fall in a declared natural disaster zone? Is there a risk of seasonal flooding, earthquakes, tremors, veld fires and landslides? Do disaster management plans exist? For assistance with the development of actions to adapt settlements to the impacts of climate change, consult the *Green book: Adapting South African settlements to climate change*[7].

(iv) Geotechnical characteristics

Open space is sometimes developed on sites with challenging geotechnical characteristics that do not allow for extensive construction. These hazardous ground conditions can affect the proposed use or layout of the open space and present risk if some construction has to take place. The following questions need to be asked regarding the ground conditions on a site:

- What is the soil condition and quality?
- Are there any aggressive chemicals or minerals present?
- Is the site part of or close to a dolomitic area?
- Was the site used for mining and exploration in the past?
- Are there large rock outcrops on the site?
- Are there gullies or other ditches on the site?
- Is there groundwater present? What is the height of the water table?
- Did dumping – legal or illegal – ever occur on the site?

(v) Existing buildings on the site

Existing buildings on the proposed development site can be viewed as either presenting opportunities or constraints. In certain cases, existing buildings could be incorporated into the open space development. To determine the most appropriate course of action, the following questions can be asked:

- Do the buildings have features of historic or conservation interest? (See Section F.3.2.1.)
- Do the buildings have cultural significance? May these buildings be demolished?
- Should these buildings be refurbished? Can these buildings be repurposed and reused? Can these buildings be integrated into the new development?
- What are the character and form of these buildings? Should this influence the remainder of the development?

(vi) Adjacent land uses and edge conditions

Adjoining properties have an impact on each other. Therefore, it is important to be aware of the land uses adjacent to the development site, as well as the edge conditions that affect the site. Questions that need to be asked include the following:

- What are the adjacent land uses and how could that influence decisions regarding the type of open space to be provided? In particular, what types of open space are available or have been planned in the neighbouring areas?
- Are there neighbouring buildings where privacy needs to be respected?
- Are there unattractive neighbouring uses from which the new open space needs to be screened?
- Are there existing streets and spaces adjacent to the site to which the new open space should relate?
- Are there noise problems from road traffic, railways or adjoining buildings?
- Is there neighbouring vegetation that may have an impact on the proposed open space?
- Does a waterway run along the edge of the site?
- Are there neighbouring buildings that have cultural significance?

(vii) Access to the site

Residents and visitors should find it easy to access public open space. Open spaces should therefore link to existing pedestrian footpaths and routes and public transport facilities. Access to the open space should also be provided at safe and convenient points. The following questions could be asked:

- What is the vehicular traffic intensity of the streets adjacent to the proposed open space? Is it busier during certain times of the day? This might influence where the different uses and facilities are placed, and how vehicular access is provided to ensure the safety of pedestrians and other users.
- Where are the existing and potential vehicular, cycle and pedestrian access points to the site?
- Are there existing footpaths or other routes (desire lines) across the site? Can the existing footpaths and routes be accommodated in the new open space? The desire lines should be considered when designing movement networks as NMT users tend to follow established routes.
- Where are public transport facilities and routes located in relation to the site? How can these be linked to the proposed public open space?
- What are the local destinations (such as shops, schools, bus stops) that users of the new open space may want to access? How can the new open space best be linked to these to encourage walking and cycling?

G.3.2.2 Available engineering infrastructure and transportation facilities

The development of open spaces may not be as infrastructure intensive as many other land uses, but the potential impact on existing engineering infrastructure (e.g. water pipelines, electricity cables, sewerage pipes) should still be considered. Transportation infrastructure (e.g. streets, sidewalks, crossings, cycle paths) should cater for motorised and non-motorised transport. To gain a thorough understanding of the existing situation, the following need to be established:

- What engineering infrastructure (bulk and local) is available close to the new open space?
- Does the existing engineering infrastructure have enough capacity to accommodate the demands (e.g. related to stormwater and sewerage handling) that will be placed on it as a result of the development of new open spaces in a neighbourhood?
- Can the new open space be linked to existing engineering infrastructure?
- Are there public transport routes close to the site? Are there bus stops, railway stations or taxi ranks close to the site? Is there sufficient public transport capacity in the area?
- Are there cycle and pedestrian facilities available?

G.3.2.3 Existing socio-economic features

The planning and design of a development must be guided by the potential needs of the residents of the new and existing neighbourhoods. If an existing community will move into the proposed development, it is critical to understand the community and involve them in the decision-making process from the outset. (See Section E.) It is also important to acquire information regarding the socio-economic features of the neighbouring communities. This will provide some indication of the types of open space that may be required. The following questions should be asked 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? This information can be used to assist with determining how much space should be provided per 1 000 people for a specific type of open space (see Table G.1).
- What is the age profile of the residents? Residents at different life stages may have different needs regarding open spaces.
- What is the income profile of the residents? Do residents have access to private cars? This will inform decision-making on issues such as the provision of parking.
- What types of housing are people living in? Some housing types (see Section H.3.3.2 for a housing typology) e.g. single detached housing or semi-detached housing often have gardens (of varying sizes) and residents may not use public open space frequently. Attached housing and apartments or flats usually have some semi-private space (e.g. courtyards), but in general, outside living spaces, yards and garden areas are limited. These residents may use public open space more frequently than people living in single detached or semi-detached housing.

G.3.2.4 Legal / administrative considerations

Legal issues relating to the site can influence the development and may cause considerable delays if not dealt with pro-actively. For the development of different types of open space, it is important to consider the zoning of the development site as it might be necessary to apply for a rezoning, a consent use or another departure from the scheme (e.g. through a building line relaxation) to accommodate the proposed development. In addition to the zoning of a property, conditions in the title deed or in the township establishment scheme or the presence of servitudes may influence decisions regarding the provision of open space.

G.3.3 Public open space options

Open spaces are often described as soft (green) or hard (paved) open spaces. Many open spaces include both soft and hard elements, but in most instances one of the elements would be more prominent. Open spaces can be classified into different types based on specific (mostly functional) characteristics. The different types can be grouped together in a number of ways according to various criteria, but for the purpose of this Guide the different types of soft open space have been categorised as follows:

- Nature reserves
- Parks
- Sites for urban agriculture
- Sports fields

The different types of hard open space have been categorised as follows:

- Squares
- Streets
- Public transport stops
- Parking lots

In practice, these eight types may manifest in various forms, permutations and combinations.

G.3.3.1 Types of soft open space

Larger soft open spaces and remnants of natural areas should, where possible, be linked by corridors of green open space. These corridors can offer opportunities for recreational walking, jogging and cycling, which is not always possible in spatially isolated spaces. The corridors can also act as conduits for indigenous species, thus potentially facilitating the movement of small urban fauna, pollinators and the dispersal of seed from one space to another. The movement of pollinators and seed enables natural systems to be protected far more effectively than in the case of unconnected natural remnants.

(i) Nature reserves

A nature reserve is an area that is protected and managed in order to preserve a particular type of habitat with its associated flora and fauna. In land use schemes, this type of open space is often zoned for 'conservation' and it frequently includes river corridors (often developed as green belts), wetlands, aquifer recharge areas, and threatened and endangered habitats. This type of open space is usually open to the public, but human activity is often restricted to certain routes or areas within the open space. It is important that the frequency of visits and the volume of users do not reach a point where they compromise the environment and interfere with the natural functioning of the ecosystem.

Human intervention in these areas should be limited and primarily be aimed at the conservation of the natural area. Rudimentary facilities such as bird hides, viewing platforms and hiking trails along rivers allow residents to use the open space in a sustainable way. The locality, size and dimensions of this type of open space are largely dependent on the existing fauna and flora and will differ from place to place.

Photo credit: Pierre Victor

Figure G.4: Nature reserves in and around human settlements help to conserve the natural environment

(ii) Parks

A park is an area of open space (in a settlement) used for recreational purposes. Parks are usually owned and maintained by municipalities. Parks typically consist of lawns, trees and gardens, but may also have buildings, playground structures, ponds, fountains, monuments, etc. Distinctions can be made in terms of size and service catchment area (e.g. neighbourhood parks and regional/district parks) or in terms of shape and form (e.g. linear parkways/greenways, pocket parks and green wedges).

Neighbourhood parks (also referred to as community, precinct or local parks) serve the needs of the people living within walking distance of the park. Neighbourhood parks create opportunities for recreation (e.g. walking, meeting friends, picnics, playing games and informal sports) by offering amenities such as lawns, gardens, seating areas, pathways and playgrounds. Neighbourhood parks can also contribute to community cohesion by providing a sense of place for a neighbourhood, especially where it incorporates a significant feature of the landscape or a historic site.

Regional or district parks cater for the needs of the broader settlement. Regional parks are not only larger in size than neighbourhood parks, they usually offer multiple and diverse activities and amenities. In addition to gardens, seating areas, walking paths and lawns, these regional parks often include playgrounds, fitness trails, sports fields and picnic spots. Larger parks are sometimes able to accommodate events like craft markets, park runs, fairs and concerts. The parks are visited regularly by people who may not live locally and who use public transport or private motor vehicles to visit the park. These parks can also be successfully clustered with certain social facilities (see Section H.4.4) or co-located with other open spaces such as sites for urban agriculture. Sometimes drop-off facilities for recyclable materials (see Section M.4.3.5) or even buy-back centres (see Section M.4.3.2) are also located at district or regional parks.

Figure G.5: Neighbourhood parks can accommodate a range of activities

Playgrounds

Playgrounds are spaces specifically provided for use by children. These facilities usually form part of a park, or they could be combined with social facilities such as clinics, community halls or libraries. Where possible, playgrounds should be located close to primary schools or Early Childhood Development (ECD) centres to facilitate the sharing of facilities. Where playgrounds form part of a park or a social facility, they should be located relatively close to entrance and exit points (but away from busy perimeter roads) and traversing pathways, so that surveillance can be optimised.

The area and dimensions of a playground vary according to the nature of the play equipment and whether the playground is part of a park, another open space or a social facility. Playgrounds should nevertheless be small enough to enable easy supervision.

Requirements for play structures and playground surfacing are addressed in *SANS 51176: General requirements and test methods for playground equipment*[8] and *SANS 51177: Impact attenuating playground surfacing*[9].

Figure G.6: Playgrounds are often incorporated into a park

(iii) Sites for urban agriculture

Urban agriculture, urban farming or urban gardening is the practice of cultivating, processing and distributing food in or around a village, town or city. Urban agriculture can include animal husbandry, aquaculture, agroforestry, urban beekeeping and vegetable gardening. Sometimes referred to as productive open spaces, the sites are often specifically used for fuelwood planting, cultivation and harvesting of medicinal plants for traditional healing purposes, and grazing for livestock.

> Sites for urban agriculture are becoming increasingly important due to concerns about climate change and sustaining food security in settlements. In addition, urban agriculture enables people to participate in the local economy and may also support cultural practices and the production of medicinal plants.

Urban agriculture initiatives are usually community based. Such open spaces may be within or close to low-income areas or accessible to the communities that are dependent on them. The size of this type of open space will vary, depending on the availability of suitable land, as well as the type of crop or livestock. Sites for urban agriculture are typically not open to the general public, but they could be combined with other social facilities such as education facilities or community centres.

Photo credit: Sibahle Community Projects

Figure G.7: Urban agriculture in a residential neighbourhood

(iv) Sports fields

Space used for organised sports can be provided in different ways. Five general types of sports facilities can be identified: stadia, fields, pools, courts and halls.[10] Certain types, such as fields and pools, can also be used for recreation (that is mostly not part of organised sports) such as walking, jogging and swimming.

It often makes sense to locate sports fields in close proximity to educational facilities or other sports facilities in order to facilitate the sharing of facilities between different user groups. Schools may for instance use the facilities during the day, while sports clubs can use them after hours or at weekends. The area and dimensions of such a sports field cluster vary according to the quantity and range of sporting codes to be accommodated, the space requirements of each sporting code, and the degree to which field markings can be overlaid to reduce space requirements. For specific field dimensions, consult the Department of Sport and Recreation's guidelines.[11]

Figure G.8: Various types of sports fields can be provided at community level

G.3.3.2 Types of hard open space

Hard open space (including squares, streets, public transport stops and parking lots) is a fundamental form-giving element in a neighbourhood (see Section F.4.6), but also provides opportunities for social interaction, economic activity and movement.

(i) Squares

Squares (sometimes referred to as plazas or piazzas) take on various forms in South African settlements. A square can be a large, paved open space with prominent buildings fronting onto the space and outdoor restaurants that are open throughout the day and evening. It may also have water features, informal traders and seating for workers during their lunch breaks. Local needs should determine the exact nature of the square to be developed, but certain universal characteristics can be identified.

Squares should be civic spaces to be used by local communities. Therefore, they are ideally located centrally in a neighbourhood where they are visible and easily accessible. Traditionally, town or city squares have held symbolic meaning as places of remembrance or celebration, reflecting shared community values. Squares are used for a variety of activities, including trade, outdoor dining, roller skating, political rallies, meeting people and concerts. Retailing often forms an important component of hard open spaces and may include formal shops as well as permanent or temporary outdoor markets. Quite often, informal trading on neighbouring sidewalks or in nearby parking lots take advantage of the pedestrian traffic created by the activities on the square.

The use of a square may change during the course of the day, week and even the year. Facilities such as restaurants, cafés, cinemas and libraries with late-night hours should be encouraged to locate alongside squares to extend the usage of the square beyond office hours. The area and dimensions of a square vary according to the functions it is intended to perform, as well as the space that is available.

Photo credit: Roadie.co.za (L)

Figure G.9: Squares can take on various forms

(ii) Streets

Streets not only facilitate movement and access, they can also fulfil a range of other functions (see **Section F.4.1**). Streets make up a significant proportion of public space (especially in urban areas) and people often depend on streets for socialising, trading and recreation. (See **Section G.2.3.2**.) Therefore, streets should be safe places for everyone – for pedestrians and cyclists as well as drivers of motor vehicles (see **Section F.4.1.5**).

A focus on people

"A key ingredient of good street design is that it is designed for people, whether those people are driving, biking, taking the bus, walking, or pausing within their surrounds. Inviting streets must typically be safe and comfortable for users, and interesting as well. In short, the street itself must become a place worth going to."[12]

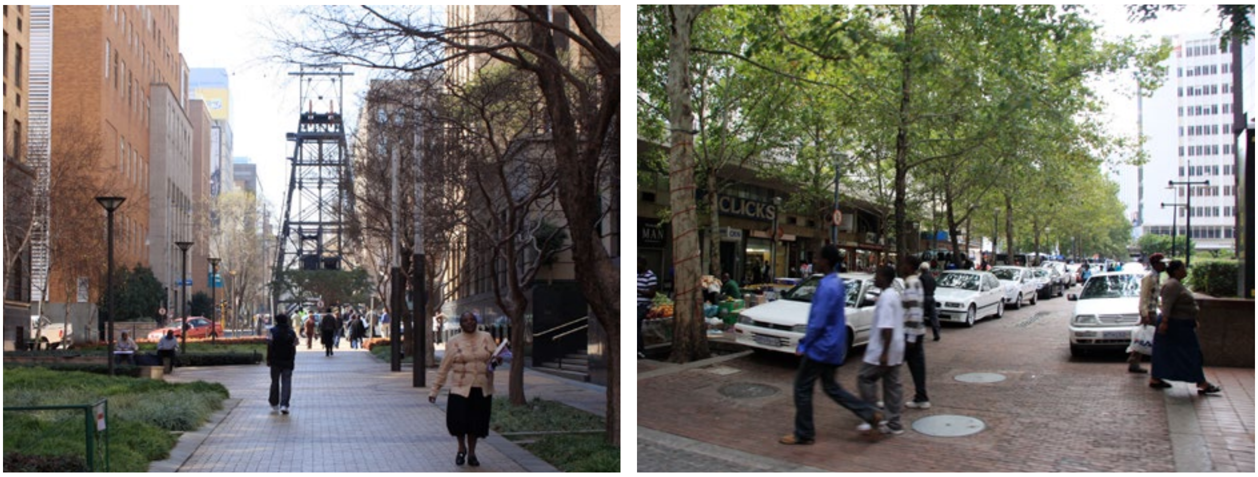

Photo credit: Annemarie Loots

Figure G.10: Examples of streets designed for people

(iii) Public transport stops

In South African neighbourhoods, public transport stops primarily include neighbourhood minibus taxi stops, neighbourhood minibus taxi ranks and bus stops (catering for municipal buses, Bus Rapid Transport (BRT) buses and others, such as long distance buses and Gautrain buses). These public transport stops should be located in places that are accessible to users (see **Section F.4**. for guidance on the role that public transport stops play in the layout and structure of neighbourhoods). The locations of bus stops are usually determined when bus routes are planned. Bus stops should be regarded as public open space and should therefore be carefully planned and designed.

Minibus taxi stops are usually not planned in advance and taxis often pick up or drop off commuters at undesignated spaces anywhere along the street.[13] However, as routes become established, stops become more permanent. Local minibus taxis also have a need for ranks or waiting areas during off-peak hours. These informal open spaces are often located near important interchanges or on the edges of neighbourhoods or simply where sufficient and conveniently located unused space is available. Unfortunately, the informal taxi stops and ranks are sometimes located at places that pose safety risks to the taxi drivers and their passengers as well as to other street users (including pedestrians, cyclists and motor vehicle drivers). Efforts should be made to engage taxi organisations in the planning and design of minibus taxi stops and ranks in neighbourhoods.

Often, minibus taxi stops become informal hubs, and the street in the immediate vicinity is transformed into a busy place where people gather. Passengers are exchanging between vehicles or between transport modes and these places usually have high pedestrian and vehicle traffic flows at certain times of the day. While some commuters may move on immediately, some have to wait for vehicles to pick them up. Provision should be made for people to queue and to wait comfortably. At taxi ranks, facilities for washing and cleaning of taxis may be provided. For more information as well as guidance regarding the planning and design of transport stops, consult the *NMT Facility Guidelines*[14] developed by the Department of Transport.

(iv) Parking lots

Parking for motorised vehicles can be provided in a number of ways, including on-street parking bays, parking garages and designated open air parking lots. Open air parking lots can be regarded as hard open spaces and should ideally be deliberately planned and designed as such. They can be located adjacent to shopping centres, *Photo credit: Gandhi Square Precinct, Johannesburg (L); Chris Kirchhoff (R) - www.brandsouthafrica.com*

Figure G.11: Examples of different types of public transport stops

office blocks and public buildings. The size and dimensions of these parking lots would depend on the specific needs of the building or area that it serves and would be determined by the by-laws and land use scheme of the local municipality. Unused vacant land could also be used as open air parking lots.

Parking lots should cater for both vehicles and pedestrians. Walkways for pedestrians should be clearly designated and must be protected from vehicular traffic. Quite often, informal traders sell their goods in parking lots. The paving, vegetation (including trees to provide shade) and public furniture used for parking lots will contribute to the quality of the open space. Opportunities exist to use these large (usually) paved areas for services other than parking (e.g. for markets, gatherings or skate boarding and other games), especially after office hours or on weekends.

Photo credit: Shawn Greyling

Figure G.12: Parking lots can be used for a range of activities

G.3.3.3 Factors to consider when planning for public open space

Factors that influence the size and number of public open spaces to be provided in a particular neighbourhood or settlement vary depending on the type of open space. For instance, decisions regarding the provision of nature reserves are usually informed by the presence of environmentally sensitive areas rather than, say, the number of possible users, as in the case of certain parks. When making decisions regarding the size and number of parking lots, other factors would be considered, such as the specific needs of the buildings or areas that they serve, and the by-laws and land use scheme of the local municipality. However, in general, open spaces should be placed throughout a settlement in such a way that they can be shared equitably by all residents. A number of issues would usually guide decisions in this regard, as discussed below.

(i) The availability and capacity of existing public open spaces

Residents not only use public open spaces that are located within their own neighbourhoods, but also public open spaces that are available in adjacent neighbourhoods or elsewhere in the settlement. Information on the number, capacity and location of existing public open spaces in and around the proposed development has to be considered (see Section G.3.2.1). The need to provide certain open spaces (e.g. parks, sites for urban agriculture, squares and sports fields) will in some cases be influenced by the presence or absence of open space in neighbouring areas and the capacity of these spaces to accommodate additional users.

(ii) The demographic profile of the residents

Another aspect that might influence the provision of certain types of public open space (e.g. parks, sites for urban agriculture, sports fields and squares) is the demographic profile of the residents of the area to be developed and of nearby neighbourhoods. Different groupings (e.g. retired people, families or single people) may use these open spaces for different purposes and they may even use them at different times of the day. A clear understanding of the differentiated needs that exist will contribute to open spaces that are appropriately designed to meet users' needs. However, the composition of the residents living in an area will change over time, with the demographic profile also likely to change.

Socio-economic status and income levels may have an impact on the type and location of parks, sites for urban agriculture, sports fields and squares. For instance, shorter travel distances to public open spaces should be prioritised in lower-income areas, as residents often have to walk (costs may prohibit them from using private or public transport) to gain access to these spaces. Certain open spaces e.g. sites for urban agriculture sometimes respond directly to the needs of lower-income communities and might be appropriate as part of such developments. People with higher incomes may select to use squares and sports fields provided by the private sector, even if these facilities are not conveniently located.

(iii) The needs of the community

If the future residents of a greenfield development are known, they could be included in the development process and could potentially inform decisions regarding the provision of public open space (see Section E). The residents of neighbourhoods surrounding a proposed development could also provide useful information to guide decisions regarding public open space. Information regarding open space needs may also be included in the municipal IDP.

(iv) Population density

Decisions regarding the provision of certain types of public open space are guided by the number of potential users in a particular area. The number and size of such open spaces can be calculated based on an estimated area (hectare) per 1 000 people. Estimated areas for parks are indicated in Table G.1. The number and size of these types of open spaces are therefore linked to population density (see **Section F.4.2.4** and **Section H.3.3.1 (ii)**). Generally, in areas with relatively high population densities, the size of certain facilities may have to be increased (compared to those provided in areas with lower densities), or more of the smaller facilities may have to be provided.

(v) Access distance

Access distance refers to the distance that people have to travel (usually from where they stay) to reach an open space. In some instances it is important to consider access distances, especially regarding open spaces such as parks, sports fields and squares. Guidance regarding ideal maximum access distances is provided in Table G.1. The area within the polygon created by these distances around a particular facility is regarded as the service catchment area. Access distances are influenced by a range of factors including the topography (e.g. flat or hilly terrain), street layout (e.g. permeable or impermeable for pedestrians), the availability of public transport, and the setting of the area (urban, peri-urban or rural). Parks, squares and sports fields that are accessed frequently by a large portion of the community should ideally be located relatively close to the target population to ensure short travelling distances and walkability (refer to **Section F.4.2.2** for a discussion on walkable neighbourhoods) for potential users of the space.

Access distance is not a determining factor in the location of all types of open space, e.g. nature reserves, public transport stops and parking lots.

Parks, squares and sports fields: Making decisions on the type, size and location

Detailed guidance regarding the equitable provision of various types of social facilities and public open space, such as parks and sports fields, is provided in the *CSIR Guidelines for the Provision of Social Facilities in South African Settlements.*[15]

The guidelines are supported by a web-based decision-making tool, the *CSIR Space Planner.*[16] Once a set of requirements (standards) for park or sports field provision has been agreed, this tool can be used to determine the impact of a specific development on the facility demand and to calculate the required space and facilities. Impact estimates are calculated for the range of facilities to be provided of specified capacity and the land area required for the provision of the said facilities.

For guidance on the application of differentiated provision standards in non-metropolitan areas (delivering parks and sports fields to rural areas), make use of the *Social Facility Provision Toolkit*[17] of the Department of Rural Development and Land Reform, which is populated with predefined standards. With this toolkit, demand can be calculated for any population size or for 1 328 predefined regional service catchment areas in South Africa for which population statistics are provided.

Table G.1: Sizes and access distances relevant to certain types of parks

Description	Ideal minimum provision/ 1 000 people	Ideal maximum access distance
General provision Description	0.4 ha per 1 000 people	-
Neighbourhood park Small (optimum size of between 1 ha and 1.5 ha) landscaped open space serving the immediate local community/neighbourhood (within walking distance). These parks usually cater for informal recreation and often include play equipment.	0.3 ha/ 1 000 people	1.5 km or 20-minute walk
Community park Larger than the neighbourhood park (optimum size of 3.5 ha), this landscaped open space serves several surrounding local communities or suburbs. These parks generally cater for a wider range of activities.		2-3 km or 30-minute walk
Regional/District park Large, multi-functional parks (minimum site size of 2 ha) that meet the wide-ranging needs of the district/ regional community. These parks often preserve unique and extensive landscapes (an example is a botanical garden).	0.1 ha/ 1 000 people	10 km or 15-minute travel by public transport

Note: The provision ratios provided in the table above could be lowered if parks are clustered with sports fields. The general guideline for the provision of neighbourhood sports fields (excluding large facilities that cater for sports at regional or international competition level) is that the land requirement should not exceed 0.56 ha/1000 people. These sports fields should ideally have a maximum access distance of between 5 and 10 km.

While it is important to provide quality open spaces that meet the needs of the community, it is also critical to ensure that these spaces can be maintained within operational budgets over the long term. The quantity of improved open space (specifically parks) is sometimes emphasised at the expense the quality of the space provided. Generally it is preferable to provide the largest possible space within the specified distance to consolidate maintenance and operation efforts and costs.

Cemeteries

Cemeteries are usually zoned as public open space that is set aside for burial purposes. Decisions regarding the sizes of cemeteries and their distribution throughout the settlement should be coordinated at a municipal level. For a method to calculate cemetery site sizes and guidelines about population thresholds and access distances to be considered in the planning for cemeteries, consult the *CSIR Guidelines for the Provision of Social Facilities in South African Settlements*[18] and the *Social Facility Provision Toolkit*[19] of the Department of Rural Development and Land Reform.

Conventional cemeteries take up large tracts of land and municipalities often have difficulty finding land that is both available and suitable for this use. An Environmental Impact Assessment (EIA) is mandatory for the establishment of a cemetery. One of the reasons why an EIA is required is because the decomposition of buried human corpses, the substances used to embalm the body, and even the materials used to manufacture caskets, could potentially result in water source contamination. Therefore, to determine whether or not a particular site is suitable for burial purposes, the following questions should be asked:[20]

- What are the soil and geotechnical conditions on the site? This is relevant as soils and underlying rock formations with, for example, high permeability or high moisture content might not be suitable for cemeteries.
- What are the groundwater conditions on the site? The water table should not be too shallow as a buffer zone is required between the bottom of the grave and the top of the groundwater table. Also, cemeteries should ideally not be located in areas of groundwater recharge or close to groundwater abstraction points. Both groundwater and surface water sources may become even more vulnerable in areas with high rainfall.
- Is the proposed site located within a 1-in-50-year floodline of a river? In general, cemeteries should not be located near any water bodies e.g. wetlands, pans, estuaries and floodplains.
- Does the site slope? Site drainage should ensure minimal ingress of surface water into the graves.

The most prevalent form of burial in South Africa is in-ground. This places a substantial demand on land, but alternatives, such as cremation or burying more than one family member in a grave, could reduce this demand. However, not everyone favours alternative methods, and other ways of reducing the need for land for traditional cemeteries, as well as the negative impact of cemeteries on the environment, should be considered. Concepts such as 'green cemeteries' or 'eco-cemeteries' should be explored, since they provide a more natural environment for burials, allowing them to also be used as a parkland or a natural habitat for animals. In these types of cemeteries, trees, stones and other natural materials are often used to mark graves rather than conventional tombstones.

For more detailed information, see *Good Practices in Cemeteries Management*[21], produced by the South African Local Government Association (SALGA). Refer to municipal by-laws for regulations regarding the procedures, methods and practices related to burial and the provision of grave plots in a municipality.

G.4 Design considerations

This section outlines the factors that need to be considered when incorporating open space into the design of a development. This section is closely linked to **Section F.4** that deals with the design of the street and plot layout of a neighbourhood. It is important to refer to **Section F.4.6** in particular when designing open space, since it provides more detail regarding the relationship between public open space and neighbourhood layout and structure.

As outlined in **Section G.3.3**, open spaces can take on various forms, including squares, streets, public transport stops, parking lots, nature reserves, parks, sports fields and sites for urban agriculture. There are significant differences between the different types and also between the different manifestations of each type. For instance, the nature and form of a park differ completely from those of a street, while the characteristics of a small neighbourhood park are not the same as those of a large regional park.

It is not the purpose of this Guide to provide detail guidance on the design of each and all of the different types of public open space. However, some level of detail is provided with respect to the design of streets, given their particular range of functions and links to other aspects of neighbourhood design. This information is provided in **Section F.4.1** and **Section I.4**. More information regarding the design of specific types of open space is also available in other guideline documents such as the *Draft Guidelines for the Provision of Open Space, 2017* [22].

A number of generic features have been identified that may be relevant to most types of open space, as well as certain aspects that would have to be considered when making design decisions regarding any of these features.

This section gives guidance regarding the design of the following generic features:

- Edges and interfaces
- Access and movement
- Surfaces and vegetation
- Public furniture and amenities

When considering the information provided below, it is important to remember that decisions related to the design of an open space should ultimately be guided by the characteristics of that particular open space and the surrounding area, as well as by local requirements and contextual features.

Designing inclusive public open spaces

When designing public open spaces and associated structures, fittings and furniture, care should be taken to create spaces that are as inclusive as possible. This means that such spaces should be welcoming and as accessible as possible to all people, including those with disabilities. More information is provided in **Section O.2**.

Sometimes certain open space components are designed to purposely and actively prevent or discourage certain residents from using a particular open space. This controversial approach is sometimes referred to as hostile or defensive architecture, or hostile design. It is usually aimed at vulnerable members of a community such as the homeless, but it could also negatively affect other people, including people with disabilities and small children. It is important to carefully consider the implications of design decisions aimed at preventing certain groups of people from using a public open space and to attempt to identify more inclusive alternatives.

G.4.1 Edges and interfaces

The boundary of an open space forms the interface between the open space and the surrounding urban fabric. The design of this boundary can influence how different land uses relate to each other. Public open space is often surrounded by private properties and the treatment of the interface between these properties and the public open space should therefore be considered carefully.

The quality of the edge between an open space and adjacent plots, or between different types of open space such as a park and a street, often plays an important role in the way in which the space is being used. In general, a clearly demarcated open space will improve the legibility of the space, which will assist people in orientating themselves and experiencing the space in a more positive way.

The edge or boundary of an open space could be defined or demarcated in various ways, depending on factors such as the local setting, the type of open space and the nature of the edge. The nature of edges could be determined by aspects such as land use, setbacks, parking requirements, access and visibility. Issues to consider when designing open space edges and interfaces include the following:

- Public open space should be integrated into the surrounding neighbourhood and, as far as possible, should not be physically or visibly isolated. This means that edges should be designed in such a way that they define the space without completely closing it off from adjacent spaces or limiting convenient access to the space. However, the degree to which a particular space is closed in and access is controlled will be determined by the type and location of that space.
- Ideally, spaces such as parks and squares should not be closed off or fenced in, to allow people to access and use the space unhindered. Walls and fences that restrict access may discourage legitimate users from accessing the space. This may result in the space being used for illicit activities and it becoming unsafe for those who want to use it for its intended purpose. It may also have a negative impact on the permeability of the neighbourhood (see Section F.4.1.1) and close off pedestrian routes, further reducing the number of casual users frequenting the space and thus limiting opportunities for natural surveillance (see Section O.1).
- In some cases there may be a valid reason why some form of fencing would be required and entrance and exit points may have to be limited, for instance to create a barrier between the users of the space and vehicular traffic in an adjoining street. Also, if a park is bordered by private houses, a secure fence separating the spaces may be required. In such instances a fence that allows for visual contact with and from adjoining spaces should be used if at all possible. Entrance and exit points should be positioned along the boundary in such a way that visitors can conveniently and safely enter and exit the park. Where applicable, the positions of the entrance and exit points should acknowledge pedestrian desire lines and public transport stops.
- For certain types of open space, the provision of a secure boundary and relatively few entrances and exits may be essential. For instance, it is often necessary to fence in sports fields, nature reserves, spaces for urban agriculture and parking lots for practical or security reasons. In such cases, solid high perimeter walls that prevent visual contact with and from neighbouring spaces should be avoided as far as possible. Blank walls facing the neighbouring spaces may create dreary or desolate areas that may not be safe for pedestrians or other people using these areas.
- The boundaries of soft open spaces such as parks can often be defined by means of the surface treatment. The horizontal surface of a soft open space may be covered with grass or other vegetation, and the adjoining space may have a hard surface (e.g. a sidewalk or street). Low fencing, shrubs or bollards could also be used to demarcate the edge.

- If buildings (whether public or private) are located on the perimeter of an open space, opportunities for natural surveillance (see Section O.1) from these buildings should be provided if possible. For instance, if a space such as a park or square is bordered by housing, windows should be provided in the walls facing the open space. Transparent fencing should be used between the open space and adjacent housing rather than solid boundary walls.
- Hard open spaces such as squares and streets can often be visually defined by placing vertical elements such as buildings or trees on the edges, thereby creating a 'sense of enclosure' (see Figure G.13). The interface between an open space and buildings facing the space should be designed with care to ensure that an active edge is created as opposed to a blank wall facing the space. An active edge can be created by providing frequent openings (exits and entrances) in the facades of the buildings facing the open space to encourage pedestrian activity as people come and go from buildings. If required, trees and shrubs could be used to soften the appearance of building facades. In the case of streets, the elements of the road reserve (see Section F.4.1.5) and the facades of the buildings along the street should be designed in an integrated way. Create an inviting and safe environment for people by clearly demarcating the sidewalk and locating activity generators such as shops, cafes, businesses and social facilities at ground level.

Photo credit: Mary Alexander (R) - www.brandsouthafrica.com

Figure G.13: Buildings and trees visually define the edge of a space and create a 'sense of enclosure'

The use of fencing

"The fencing-off of parks and similar open spaces is usually inadvisable. Barriers may deter legitimate users from entering, and reduce movement through these spaces, and thereby hamper natural surveillance. They may also provide a false sense of security since fences does not always prevent those with criminal intent from entering. It may often be sufficient to demarcate a specific area through the use of low, transparent fences, for instance to define a playground for children"[23] (see Figure G.14).

Figure G.14: Low fencing and elements such as bollards could be used to define a space

G.4.2 Access and movement

When making decisions regarding access to, and movement around and within, open spaces, the following should be taken into consideration:

- Open spaces can be linked to the surrounding area by extending neighbourhood pedestrian and cycle routes into or through the open space. Where applicable, entrances and exits, as well as routes through an open space, should acknowledge existing pedestrian desire lines. Care should be taken to ensure that vehicles, pedestrians and other non-motorised transport have safe access to an open space. Streets and sidewalks bordering the open space, as well as related intersections, pedestrian crossings and entrance and exit routes should be designed with care. For detailed design guidance on pedestrian crossings, refer to the Department of Transport's *National Technical Requirement 1: Pedestrian Crossings*[24] of 2016.
- Open spaces should be accessible to all users, including people with disabilities. The principles of universal design as outlined in **Section O.2** should be applied wherever possible. In particular, pathways within open spaces, and those linking such spaces to the surrounding area, should specifically be provided to accommodate wheelchair users, prams, pedestrians and cyclists (see **Section I.4**). They should be wide enough and the gradients should meet the requirements set out in Part S of the *National Building Regulations.*[25]
- Pedestrians and vehicles (including non-motorised transport) should be guided through an open space in such a manner that all users are safely accommodated, and where applicable, ecologically or culturally sensitive areas within the open space are protected. Movement could for instance be guided by means of pathways and by the positioning of lighting. The presence of lighting could direct users along safe and preferred routes, while the absence of lighting could discourage them from visiting certain areas at night and guide them along a safer route (see **Section G.4.4**).

G.4.3 Surfaces and vegetation

To select suitable vegetation and horizontal surface-covering material for different types of open space, various factors should be considered, including the following:

- The primary purpose of the open space will be a key determinant of the type of surface covering to be used. In some cases the choice would be obvious – for instance, parks, soccer or rugby fields would primarily have grass surfaces. Artificial (synthetic) grass is becoming popular for certain applications. However, before deciding on this option, the advantages and disadvantages should be considered. Be aware that artificial grass may not allow all rainwater to seep into the soil, it absorbs heat, and it could become very hot to the touch when exposed to sunlight.
- In areas where children may be active and perhaps fall, such as playgrounds, a surface material should be used that meets the specifications contained in *SANS 51177: Impact attenuating playground surfacing.*[26]
- Surfaces are often paved to provide the users of an open space with an area that is dust and mud free, especially in the case of transport stops, open parking lots, sidewalks, pathways, etc. Care should be taken to ensure that the surface material used does not pose a risk for people with disabilities or other users who may have mobility difficulties, such as the elderly. Certain paving material may be characterful and visually appealing, but they may make it difficult for these users to move safely and with ease. Where appropriate, material that assists users with disabilities to find their way should be used (see Section O.2). Paving material that allows for the comfortable movement of wheelchairs, prams, bicycles, etc. and tactile surfaces to assist those that are visually impaired, should be used where possible.
- Where possible, open space should be designed to support the principles of Water Sensitive Design (WSD) (see Section G.2.3.1). If appropriate, integrate public open space networks with stormwater management systems (e.g. retention ponds, aquifer recharge areas and open water canals). Permeable paving could be used to allow water to drain effectively, while vegetation swales and depressions may reduce runoff (see Section L). Open spaces should be designed and landscaped appropriately to ensure that they make a positive contribution to the environment and the surrounding community, and they do not become unkempt pieces of vacant land.
- Vegetation such as shrubs, trees and flowers should be suitable to the local habitat and climatic conditions. Select vegetation options that reduce water consumption, increase shading and can potentially adapt to climate change conditions, e.g. by having a wide temperature tolerance range. Minimise the use and reliance on potable water. Investigate options for rainwater harvesting, stormwater harvesting or greywater harvesting (see Section J.4.2).

Photo credit: Annemarie Loots (R)

Figure G.15: Vegetation could help to create open spaces that are interesting and inviting

G.4.4 Public furniture and amenities

Public furniture (also known as street furniture) refers to seating, waste bins, water features, lighting fixtures, etc. that are used in open spaces. The comfort of all potential users should be considered when decisions are made about the provision of public furniture. The following should be kept in mind:

- All public open spaces, in particular movement routes and areas where people would congregate (e.g. transport stops, parking lots and sidewalks) must be well lit at night to ensure the safety of users. Light fittings should be chosen according to the function they need to fulfil. For instance, low-level lights could be used to illuminate pathways, while certain parks or squares may require higher-level lights that illuminate large areas (see Figure G.16).

Figure G.16: Lighting can improve safety and can create a pleasant atmosphere

- In most instances, public furniture should be robust and the material used should be able to withstand the elements and being misused.
- Where appropriate, public furniture should be multi-functional. For instance, planters or bollards could be designed in such a way that they can double as seating (see Figure G.17).

Photo credit: Annemarie Loots (L)

Figure G.17: Public furniture includes bollards and planters that can also be used as seating

- Public furniture should accommodate the needs of different user groups. For instance, waste bins should be placed at a height that would allow children to use them. Furthermore, elements such as benches, waste bins and light fittings should be positioned in such a way that they do not obstruct routes taken by, for instance, pedestrians, cyclists or those making use of wheelchairs.
- In certain public open spaces, it may be useful to provide amenities for informal traders. Such amenities should be located carefully in areas where there would be potential customers (e.g. where there will be foot traffic or where people will congregate such as at a transport stop). If the amenities are not well located, informal traders will not make use of them and continue to trade where they know there will be customers.
- Streetscape elements should be aligned and visible and should not be in the way of pedestrians, cyclists or vehicles. For instance, if bollards or raised traffic islands are used, they must be either high enough to be visible to approaching drivers or be low enough that they cannot cause damage to vehicles driving over them.
- Toilet facilities in public open spaces should always be designed carefully to ensure that all users are safe and opportunities for crime are minimised (see **Section O.1**). The facility should be located in an area that allows opportunities for natural surveillance from the surrounding area, for instance by locating it close to areas with high levels of activity such as a restaurant or coffee shop. Entrances should not be hidden and ample lighting should be provided.
- Restaurants, coffee shops and similar types of amenities should be located and designed in such a way that they contribute to the creation of a safe environment. They are activity generators that increase opportunities for natural surveillance. If, for instance, a children's playground is located near a restaurant, it will be possible for the restaurant customers to keep an eye on those using the playground.
- In some cases, public furniture or amenities could be provided to attract visitors and thereby increase the number of people making use of a particular open space. For instance, a wishing well, water feature, robust exercise equipment or a skate park could be provided depending on the type of open space (see Figure G.18). This could have various benefits, for instance it could improve levels of actual and perceived safety and it could increase the number of shoppers or customers.

Figure G.18: By providing, for instance, exercise equipment or a skate park, people may be attracted to open spaces

Design to enable effective maintenance of public open space

Public open spaces should be regularly and effectively maintained to ensure that they remain in a functioning and useable condition. Unkempt, run-down or vandalised spaces create the impression that they are neglected and may have been abandoned by those responsible for their upkeep and management. This often creates the impression that such spaces are unsafe, which discourages legitimate users from using them. This may result in these spaces not being used at all, or they may be used for unauthorised activities rather than for the purpose initially intended. This may place a strain on the authority responsible for the open space and may negatively affect the surrounding neighbourhood.

It is therefore essential that open spaces are designed in such a way that they could be maintained relatively easily. This may mean, for instance, that materials should be specified that do not require regular, specialised or expensive maintenance. In particular, light fittings should be as durable and vandal resistant as possible (without being unsightly). Care should be taken when designing certain elements such as bins, gates and fencing to avoid them being removed to be repurposed or to be sold as scrap metal.

Figure G.19: Public furniture include lighting, benches and rubbish bins

Glossary, acronyms, abbreviations

Glossary

Biodiversity
The variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. It also includes diversity within species, between species and of ecosystems.

Cultivated area
An area that is still perceived as predominantly 'green' but no longer in its natural state. It has been developed by human intervention for human use.

Desire line
An imaginary line linking facilities or places, which would form a convenient and direct route for pedestrians and cyclists. Desire lines become evident when watching people move through an area and they are often visible through informal footpaths across open space.

Ecosystem
A dynamic complex of animal, plant and micro-organism communities and their non-living environment interacting as a functional unit.

Habitat
A natural place or type of site where a specific species or organism occurs naturally. This area is characterised by specific physical factors such as soil, moisture, temperature range, availability of light as well as biotic factors such as the availability of food and the presence of predators.

Land use scheme
A land use scheme forms part of a land use management system that regulates and manages land use within a municipality. The scheme confers legal rights to properties to develop and to erect and use buildings subject to certain stipulated conditions. A detailed description of the content of a land use scheme is provided in Chapter 5 of SPLUMA.

Legibility
Legibility refers to the ease with which a space or a structure can be understood and navigated as a whole. People are therefore able to 'read' their surroundings. Legibility can be improved by providing physical elements that can serve as reference points.

Natural landscape
An area where biophysical processes and land features predominate over cultural elements. Few areas are totally pristine and all natural areas are in a dynamic state and to some extent involve contact with people.

Plot

A measured piece of land, also known as an erf, stand or site that is registered at the Deeds Office or forms part of a municipal land use scheme.

Rezoning

A colloquial description of the process of making an amendment to a land use scheme (or any of its provisions), to change the land use rights and development restrictions applicable to a specific property.[27]

Road reserve

A road reserve is a legally described area within which facilities such as roads, footpaths and associated features may be constructed for public movement. It is the total area between boundaries shown on a cadastral plan. It may also include an area alongside the road that may in future be used for expansion of the road width.

Sense of place

The sense of place of a neighbourhood can be described as the attitudes and feelings that individuals and groups hold towards the neighbourhood. Sense of place is therefore subjective, but useful generalisations can be made e.g. that some spaces, at least for most people who encounter them, provide an experience that is going to be unique, place-specific rather than generic. Places that have unique characteristics and histories are often considered to have a heightened sense of place. Layers of history, unique architecture or layouts, and place-specific signs and symbols help differentiate one place from another. But sense of place is not just about the physical environment, it also entails our perceptions of the positive social interactions that we partake in and those that we observe within a neighbourhood.[28]

Servitude

A servitude is a registered right that a person or an entity has over the immovable property of another person. It usually means that a portion of land is set aside for a specific purpose, such as road widening, or provision for engineering infrastructure (e.g. water pipelines, electricity cables, sewerage pipes). The municipality might for example have the right to construct electricity cables over a privately owned property. The property owner is then restricted in what he or she can do within the servitude. The servitude is attached to the property and will continue to exist even if ownership of the land changes. The servitude forms part of the conditions contained in the title deed and can only be cancelled by agreement between both parties.

Spatial Development Framework

SPLUMA requires all three spheres of government to produce Spatial Development Frameworks (SDFs). The focus of the three types of SDF differ. The national SDF provides broad strategic direction, provincial SDFs focus on the coordination of spatial development, and a municipal SDF contains detailed plans for the particular area of jurisdiction. Within the municipal sphere, the SDF forms a core component of the Integrated Development Plan (IDP) and guides the overall spatial distribution of current and desirable land uses within a municipality to give effect to the vision, goals and objectives of the municipal IDP. A detailed description of the content of SDFs is provided in Chapter 4 of SPLUMA.

Title deed

A title deed is a document from government that stipulates who the owner of the property is, the property's land use zoning and associated rights, as well as any restrictions such as servitudes, amended building lines, and area-specific conditions.

Universal design
The design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people, regardless of their age, size, ability or disability.

Wetland
The National Water Act defines a wetland as land that is transitional between terrestrial and aquatic ecosystems, where the water table is usually at or near the surface, or the land is periodically covered by shallow water that naturally supports vegetation typically adapted to life in saturated soil.

Zoning
A property's zoning stipulates the purpose for which the land may be used and is described in the municipality's land use scheme. The zoning also stipulates restrictions on the building erected on the property in terms of floor area ratio, coverage, density, parking requirements, etc. In order to change the purpose for which the property can be used, an application for rezoning has to be submitted to the local municipality for consideration.

Acronyms and abbreviations

BRT	Bus Rapid Transport
CBA	Critical Biodiversity Area
ECD	Early Childhood Development
EIA	Environmental Impact Assessment
ESA	Ecological Support Area
GHG	Global Greenhouse Gas
IDP	Integrated Development Plan
NEMA	National Environmental Management Act
NMT	Non-Motorised Transport
SANBI	South African National Biodiversity Institute
SANS	South African National Standards
SDF	Spatial Development Framework
SPLUMA	Spatial Planning and Land Use Management Act
SuDS	Sustainable Drainage Systems
WSD	Water Sensitive Design

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Section H
Housing and social facilities

The Neighbourhood Planning and Design Guide

Part II

Planning and design guidelines

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 H
Housing and social facilities

The Neighbourhood Planning and Design Guide

Table of contents

H.1 Outline of this section

H.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 housing and social facilities in this system. Information is provided to guide decision-making regarding the provision of an appropriate mix of different forms of housing, and also regarding various types of social facilities that could be provided.

It is estimated that housing accounts for more than 70% of land use in most cities[1], and therefore it is a structuring element that has a significant impact on the liveability and vitality of settlements. The range of housing options provided as part of a development, and their location, could contribute meaningfully to the quality of residents' living environments. The need for a differentiated response to the provision of housing that allows for, and responds to, contextual characteristics and locational challenges is emphasised in this section.

Access to social facilities is a key characteristic of positively performing neighbourhoods. A social facility is any place where a social (or public) service is offered by the government or private and non-profit organisations, including health, education, civic, recreation, cultural, security and safety, socialising and communication services. Social facilities are sometimes referred to as public facilities.

The aspects addressed in this section therefore play an essential role in achieving the vision for human settlements outlined in **Section B**, and relate in particular to **Section F** which deals with neighbourhood layout and structure, and **Section G** (Public open space).

H.1.2 Content and structure

This section (Section H) is structured to support effective decision-making related to the provision of housing and social facilities. The decision-making framework is outlined in Figure H.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 housing and social facilities 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 housing and social facilities 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 housing and social facilities that are available for consideration

Design considerations

Guidelines to assist with the design of housing and social facilities.

Glossary, acronyms, abbreviations

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

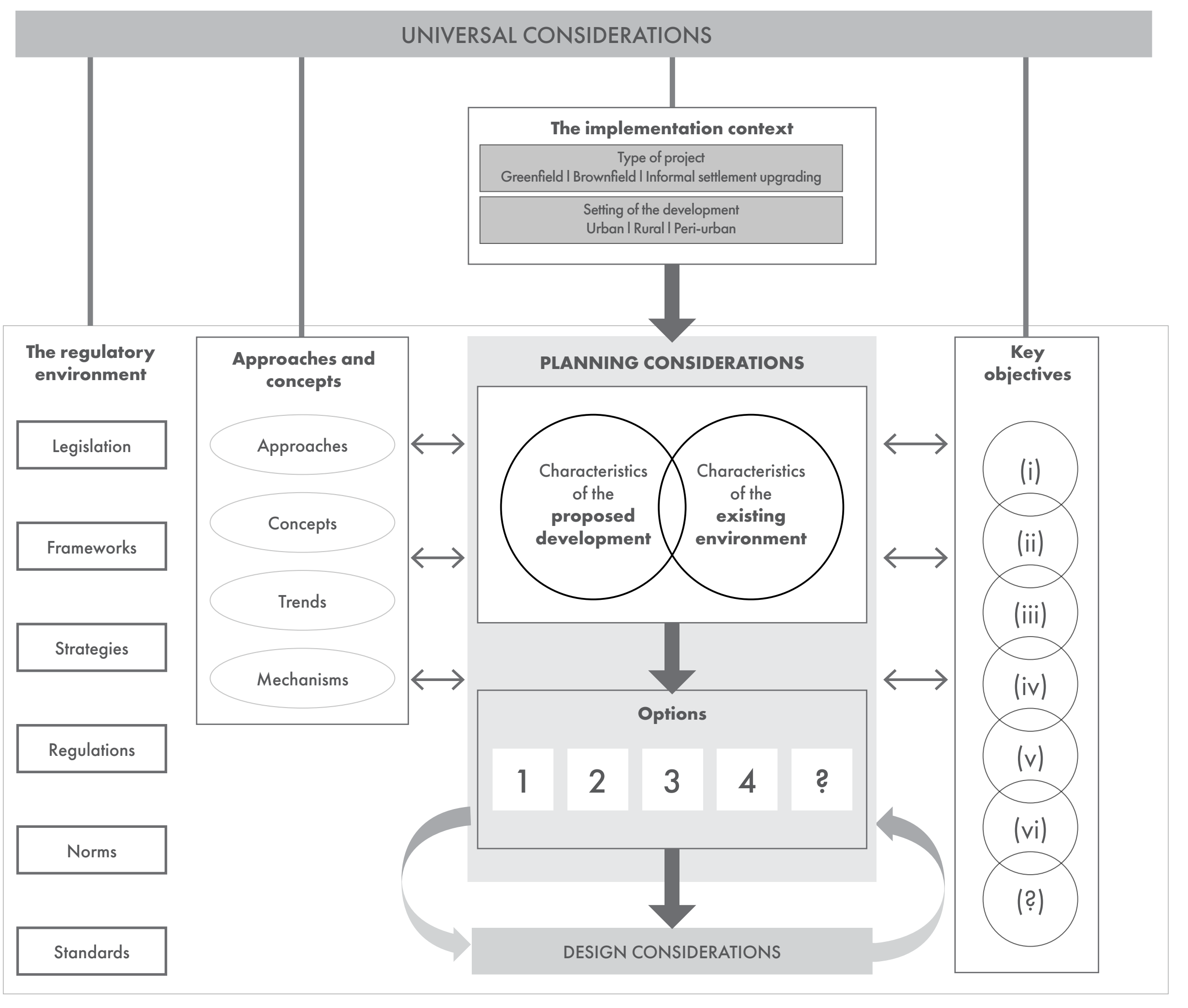

Figure H.1: A framework to assist with planning and design decisions

H.2 Universal considerations

H.2.1 The regulatory environment

A range of legislation, policies and strategies guide the provision of housing and social facilities in South Africa. 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 (NBR)* available from the South African Bureau of Standards (SABS).[2] In addition, local municipalities may have guidelines, regulations and by-laws that may be applicable.

Housing

The provision of housing is governed by, among others, the following:

- The Housing Act, 1997
- The Social Housing Act, 2008
- The Rental Housing Act, 1999
- The Housing Consumers Protection Measures Amendment Act, 2007
- The Sectional Titles Schemes Management Act, 2011
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- The Community Schemes Ombud Service Act, 2011
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- The Home Loan and Mortgage Disclosure Act, 2000
- The Prevention of Illegal Eviction from and Unlawful Occupation of Land Act, 1998
- Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements, 2004
- The National Housing Code, 2009

Social facilities

The planning and design of certain social facilities are also subject to legislation and prescribed norms and standards, including:

- The South African Schools Act, 1996
  - Regulations Relating to the Minimum Uniform Norms and Standards for Public School Infrastructure, 2013
- The National Health Act, 2003
  - Norms and Standards Regulations in Terms of Section 90 (1)(b) and (c) of the National Health Act, 2003, applicable to Certain Categories of Health Establishments, 2015
  - National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners, 2015
- The Children's Act, 2005
- Blue Print, Minimum Norms and Standards for Secure Care Facilities in South Africa, Department of Social Development, 2010

- Norms and Standards for Sport and Recreation Infrastructure Provision and Management, Volumes 1 and 2, Department of Sport and Recreation South Africa, 2011

H.2.2 Key objectives

Housing and social facilities should contribute to the creation of liveable neighbourhoods and settlements that enhance everyone's quality of life. The following objectives should guide decisions regarding the provision of housing and social facilities:

- Provide a range of dwelling types and tenure options that meet different needs and requirements and, where relevant and appropriate, make housing opportunities available to all, regardless of financial abilities.
- Design housing and social facilities such that they promote community wellbeing and strengthen social cohesion, by, for instance, creating an interactive relationship between buildings and open spaces, especially neighbourhood streets.
- Provide social facilities equitably and locate them such that they are within a reasonable distance from the people they are intended to serve.
- Use housing and social facility clusters to structure neighbourhoods in such a way that urban sprawl is minimised and more effective and efficient spatial patterns are promoted.
- Provide housing that includes basic services and infrastructure to ensure that the occupants have safe drinking water, adequate sanitation, and energy for cooking, heating and lighting.
- Ensure that housing provides the occupants with a safe space with structural integrity that affords them protection against the cold, heat, rain, wind as well as health hazards.
- Allow for changing needs and conditions by planning and designing housing and social facilities in such a way that, if necessary, they can be adapted when circumstances change over time.
- Design housing and social facilities such that they can be accessed by all, including people with disabilities, and regardless of age.
- Provide housing and social facilities in a manner that does not have a negative impact on the environment and reduces reliance on non-renewable resources.
- Provide housing and social facilities that are culturally accommodating and responsive to the local heritage setting.

H.2.3 Approaches and concepts

H.2.3.1 Incremental housing

The concept of incremental housing is referred to by different terms, and a range of different methods are, and have been, used to implement this approach to housing delivery. In essence, it involves the provision of a house in stages over an extended period of time rather than as a complete unit. It usually involves government providing a site with some service infrastructure, allowing owners the opportunity to provide some form of house themselves as and when they are able to do so. The intention is for the owner to take responsibility for building the initial structure and then expanding it over time.

The incremental housing approach could be challenging due to the more informal, less conventional nature of the delivery process. This approach relies on the active and committed involvement of owners and the community. It could be an appropriate way of providing more citizens with access to housing opportunities than would be possible with conventional delivery methods.

The incremental housing approach (NUSP[3])

"Basically, incremental housing is a process whereby households build and extend their houses on an ad hoc basis in response to their needs and the availability of resources. Generally it is an approach used by households with low or irregular incomes, and limited or no access to credit and loans, who start by building a small affordable dwelling. Over time they expand and improve the house based on their needs and resources."

H.2.3.2 People-driven housing

The people-driven approach involves community members (referred to as beneficiaries) in all aspects of the housing delivery process. Community members actively participate in decision-making regarding the housing process and the housing product, such as location, layout, services, tenure and house design.

Communities often drive the process and are involved in building their own houses and in organising and managing the building process. They make a contribution to the cost of the house, and if this is combined with a subsidy, the end product usually responds more appropriately to the needs of the residents.

H.2.3.3 Repurposing and retrofitting

Repurposing existing buildings, also known as adaptive reuse, is one strategy that can be used to minimise land costs. Adaptive reuse refers to the repurposing of existing vacant and/or under-utilised buildings for a purpose other than which it was originally built or designed for, either in part or in whole. Adaptive reuse is a key factor in resource conservation (land, energy and material), in optimising existing bulk infrastructure, and in containing urban sprawl. Adaptive reuse is often a preferred option for heritage conservation where a building that is conservation worthy is no longer financially viable in its original use.

Repurposing and retrofitting allow for the provision of housing and social facilities in buildings that may not originally have been designed for these functions. Abandoned buildings in the inner city, or unused office blocks may provide ideal opportunities for this type of adaptive reuse.

H.2.4 The implementation context

This section highlights the contextual factors that should be considered when making decisions regarding housing and social facilities, specifically related to the type of development and its setting. Also refer to **Section D.2.1** (Type of development) and **Section D.2.2** (The setting/location of the planned development).

H.2.4.1 The type of development

(i) Greenfield development

Greenfield projects can theoretically accommodate most housing types. The deciding factor would normally be the income level of the anticipated residents of the new development. Other factors that would influence the forms of housing that could be provided include the topography and geotechnical conditions. Greenfield sites often raise concerns regarding urban sprawl. Decisions regarding housing types would play a role in determining densities and could therefore assist in addressing these concerns.

The provision of social facilities needs to be based on a thorough assessment of the surrounding area to understand what is available and the extent to which these facilities will be accessible to the residents of the planned neighbourhood.

(ii) Brownfield development

The types of housing that could be provided on brownfield sites would be influenced by the nature of the existing physical and socio-economic environment within which the development will be located. For instance, infill developments, retrofitting and the subdivision of large residential stands will require different types of housing options. A brownfield site may have existing structures that may be vacant or derelict and could be repurposed as residential units. Decisions regarding housing types will also be influenced by the availability and capacity of engineering infrastructure, such as electricity supply and sanitation services. In certain cases, the features of the built environment may provide design clues that could influence the physical appearance of the houses provided.

Since brownfield sites are normally part of the fabric of an existing city or town, some social facilities may be readily accessible. However, this should not be assumed, and new facilities should be incorporated into the planning if required. Care should also be taken to ensure that the upgrading or redevelopment of an existing area does not put additional strain on social facilities in the surrounding neighbourhoods.

(iii) Informal settlement upgrading

Informal settlement upgrading projects are usually complex undertakings that require extensive community participation, specifically with respect to the housing to be provided. Options may have to be developed to address specific requirements, for instance by providing a site with access to water and sanitation services, while allowing for the incremental development of the house itself. Acceptability and perceptions may be important factors to address when making decisions regarding housing options.

The provision of social facilities should be an important component of an informal settlement upgrading project. It could contribute to the creation of a liveable and well-functioning new neighbourhood. Informal settlements could be located close to an established part of a city or town or on the periphery, removed from existing services and amenities. Access to existing social facilities therefore needs to be taken into consideration and new facilities should be planned for as part of the upgrading initiative if needed.

H.2.4.2 The setting of the development

(i) Urban

Urban settings can take on different forms, and therefore developments will vary in nature. Urban areas include central business districts, residential suburbs, informal settlements, and what used to be referred to as townships, and this will influence the type of housing to be provided. In some cases detached housing may be a suitable option, while semi-detached or attached housing may be better suited, for instance for an infill development. The social facilities to be included in an inner-city development will also differ from those required in, for instance, a suburban setting.

(ii) Peri-urban

Given the transitional nature of peri-urban areas, the nature of developments will vary considerably, and so will the types of housing and forms of social facilities to be provided.

(iii) Rural

Development sites in rural areas will vary in nature depending on the location, for instance whether it is situated in a rural town or a dispersed settlement. The housing types appropriate to the setting will therefore also vary and the nature of the housing options provided will be dictated by a range of factors. In some cases the housing form may be influenced by cultural considerations, the ownership of the land and tenure arrangements (for instance if it is under the control of traditional leadership).

Due to lower population densities, the provision of social facilities in rural areas may sometimes require an approach that differs from that taken in cities or towns. It may have to be accepted that some facilities cannot be provided, while other facilities may be absolutely essential even though they may serve relatively few people.

H.3 Planning considerations

This section deals with the planning of the provision of housing and social facilities. 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 housing and social facility options based on a thorough understanding of the context within which the planned development will be implemented.

The decisions regarding the provision of housing and social facilities 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 existing services and infrastructure that could be utilised must be identified.

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

H.3.1 Characteristics of the proposed development

Decisions regarding housing and social facilities 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 briefly discussed below.

H.3.1.1 The nature of the proposed development

Various factors related to the nature of a development could influence decisions regarding the provision of housing and social facilities. For instance, smaller projects may not be able to accommodate a wide range of housing options and it may not be necessary to include social facilities in the project. Large (or mega) projects may have to include a wide range of housing types and require the inclusion of various social facilities. Mixed-use, mixed-income projects and projects that are primarily residential in nature would also need different approaches to the provision of housing and social facilities. 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 housing options and social facility provision.

H.3.1.2 The residents of the area to be developed

Decisions related to the types of housing and social facilities that should be provided in a development need to be guided by information regarding the potential residents and users of the planned facilities. Usually, the identities of the actual occupants of the houses to be provided are not known when a development is planned and designed. It is also difficult to predict who will make use of social facilities, either as service providers or as the beneficiaries of services. It may be possible to make assumptions regarding the possible nature of the future residents and users of social facilities by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to establish the following:

- The total number of residents that would have to be accommodated. Actual numbers may be higher than anticipated due to the fact that the provision of houses and 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 which types of housing would have to be provided and which types of social facilities may need to be considered.
- The range of residents with special needs that would have to be accommodated, e.g. people living with HIV/Aids and with disabilities, including physical, dexterity and sensory impairment. Housing types and social facilities should, as far as possible, be accessible to all residents and users.
- Age and gender of residents and those that may visit social facilities (i.e. gender ratios or age profile). An ageing population might, for example, require access to housing or social facilities at a ground level, as opposed to walk-ups or apartments. It could also indicate the need for specific types of social services aimed at the youth or the elderly.
- Income and employment levels and spending patterns. This would, for instance, indicate to what extent housing would have to be able to accommodate motor vehicles, and what types of social services would be most appropriate.
- Cultural profile. The mix of the target group is also important to consider, as the social structure could shape the demand for some housing types at the expense of others.

H.3.2 Characteristics of the existing environment

Decisions regarding housing and social facilities 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.

H.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the site could influence the types of housing and social facilities to be provided.

(i) Topography

The topography of the project site is a key factor when making decisions regarding the layout of the development, and as such it will also guide decisions regarding the provision of housing and social facilities. The topography will influence the micro-climate of the site and have a significant impact on the provision of municipal engineering services. The following questions need to be asked:

- Does the site slope? Are there significant changes in level such as embankments or retaining walls? A sloping site could mean that additional costs would have to be incurred when constructing houses and other buildings. It may also be difficult to provide certain housing types on very steep sites.
- How will the slope or level changes affect the site layout and the positioning of buildings? It may be difficult to position houses and other buildings facing north, or it could be difficult to provide vehicle access to the plot.
- Can the development be oriented to make the most of attractive views? Sometimes the view (prospect) and sun (aspect) are in conflict, and compromises will have to be made.

(ii) Climate

The micro- and macro-climates of the site will affect on aspects such as street layout and plot orientation. It is imperative that the site be physically inspected and that this occurs at different times of the day, preferably even different times in the year. A site that is warm in summer may be cold in winter, because of, for instance, the topography. A physical inspection will provide clues about where the building would be best located. The following questions need to be asked:

- Is the site exposed to prevailing winds? Is the wind direction seasonal? This information would assist in positioning a building on a plot to, for instance, make use of the wind to cool the interior, to ensure that outside living spaces are protected from the wind and to promote natural ventilation for the prevention of airborne contagion.
- Where does the sun rise and set in summer and winter? There may be external features that influence sun penetration on the site, such as a nearby mountain or hill, tree, or building.
- Does the site fall in a declared natural disaster zone? Is there a risk of seasonal flooding, earthquakes, tremors, veld fires, and landslides? Do disaster management plans exist? For assistance with the development of actions to adapt settlements to the impacts of climate change, consult the *Green book: Adapting South African settlements to climate change*[4].

(iii) 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 might not be suitable for construction. The ground conditions could also have implications for the population density or housing density that can be accommodated on the particular site. The following questions need to be asked:

- What is the soil condition and quality?
- Are there any aggressive chemicals or minerals present?
- Is the site part of or close to a dolomitic area?
- Was the site used for mining and exploration in the past?
- Are there large rock outcrops on the site? Are there gullies or other ditches on the site?
- Is there ground water present? What is the height of the water table?
- Did dumping – legal or illegal – ever occur on the site?

(iv) Landscape and ecology

The physical features of the landscape could have a substantial impact on the types and positioning of housing and social facilities that can be provided. A thorough analysis of the landscape and ecology should be conducted to determine if there are certain parts of the project site that would not be suitable for development. If the site is located in or near an ecologically sensitive area, there may be restrictions that could influence the positioning (and ease of construction) of houses and other buildings. 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 or underground 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) and Ecological Support Areas (ESAs) is available on the website of the South African National Biodiversity Institute (SANBI)[5].

- Endangered or protected plant or animal 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.

(v) Existing buildings on the site

If there are existing buildings on the proposed development site, they can be viewed as either presenting opportunities or constraints. In certain cases, existing buildings could be incorporated into the development by converting them into housing or social facilities. To determine the most appropriate course of action, the following questions can be asked:

- Do the buildings have features of historic or conservation interest? (See **Section F.3.1.1 (v)**)
- Do the buildings have cultural significance? May these buildings be demolished?
- Should these buildings be refurbished? Can these buildings be repurposed and reused? Can these buildings be integrated into the new development?
- What are the character and form of these buildings? Should this influence the remainder of the development?

(vi) Adjacent land uses and edge conditions

Adjoining properties have an impact on each other. Therefore, it is important to be aware of the land uses adjacent to the development site as well as the edge conditions that affect the site. Some of the questions that need to be asked include the following:

- What are the adjacent land uses and how could that potentially influence decisions regarding the housing and social facilities to be provided as part of the proposed development?
- Are there neighbouring buildings where privacy needs to be respected?
- Are there unattractive neighbouring uses from which the new development needs to be screened?
- Are there existing streets and spaces adjacent to the site to which new development should relate?
- Are there noise problems from road traffic, railways or adjoining buildings?
- Is there neighbouring vegetation that may be affected by the development of the site?
- Are there neighbouring buildings that have cultural significance?

(vii) Access to the site

Residents and visitors should find it easy to access housing and social facilities. The positioning of housing and social facilities in a development should therefore be influenced by the location of access points, existing footpaths and routes on the site, and public transport facilities. The following questions need to be asked:

- What are the existing and potential vehicular, cycle and pedestrian access points to the site?
- Are there existing footpaths or routes (desire lines) across the site? Can the existing footpaths or routes be accommodated in the new development?
- Where are public transport facilities located in relation to the site? How can these be linked to the proposed housing and social facilities?
- What are the local destinations (such as shops, schools, bus stops) that occupants of the new project will be wanting to access? How can the new development best be linked to these to encourage walking and cycling?

H.3.2.2 Available engineering infrastructure and transportation facilities

Developments create additional demand for services (engineering and transportation) and therefore have a potential impact on existing engineering infrastructure (e.g. water pipelines, electricity cables, sewerage pipes) and transport infrastructure (e.g. streets, sidewalks, crossings, cycle paths). Infrastructure provision and the provision of housing and social facilities are intrinsically linked, therefore the following needs to be established:

- What engineering infrastructure (bulk and local) is available close to the new development?
- Does existing engineering infrastructure have enough capacity to accommodate the new development?
- Can the new development be linked to existing engineering infrastructure?
- Are there public transport routes close to the site? Are there bus stops, railway stations or taxi ranks close to the site? Is there sufficient public transport capacity in the area?
- Are there cycle and pedestrian facilities available?

H.3.2.3 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. If an existing community will move into the proposed development, it is critical to understand the community and involve them in the decision-making process from the outset (see Section E). It is also important to acquire information regarding the socio-economic features of the neighbouring communities. This may provide some indication of the housing types that may be required and the social facilities that may have to be provided. The following questions should be asked 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? This information will be used to calculate population thresholds for the provision of social facilities.
- What is the average size of households in the area? Different household sizes may affect issues such as the size of the dwelling units that will be provided.
- What is the age profile of the residents? Residents at different life stages might have different needs regarding social facilities and housing types.
- What is the income profile of the residents? Do residents have access to private cars? This will inform decision-making on issues ranging from parking provision to the maximum distances that people are able to travel to reach social facilities.
- What is the employment profile of the residents? This may have an impact on the provision of certain social facilities, e.g. Primary Health Care clinics.

H.3.2.4 Access to existing social facilities

To determine the requirements for social facilities in the proposed development, it is important to know the number of existing facilities in the neighbourhood, the services they offer, as well as the capacity of these facilities. The following questions could be asked:

- How many social facilities are available in the neighbourhood, in adjacent neighbourhoods and in the settlement?
- What types of social facilities, for instance schools, police stations and clinics are available in neighbouring areas? How far are these facilities from the development site? Are the routes linking the development site with

existing social facilities suitable for non-motorised transport or serviced by public transport? Do these facilities have spare capacity?

- What services are offered at the existing social facility? Is the facility over-utilised or under-utilised? Is there space for the increase of service delivery capacity at the existing social facility?
- Will the community be using public or private facilities? This may be relevant to healthcare, education or recreation facilities.

H.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. For the development of housing and social facilities, it is important to consider the zoning of the development site as it might be necessary to apply for a rezoning, a consent use or another departure from the scheme (e.g. through a building line relaxation) to accommodate the proposed development. In addition to the zoning of a property, conditions in the title deed or in the township establishment scheme or the presence of servitudes may influence decisions regarding the provision of housing and social facilities.

H.3.3 Housing options

H.3.3.1 Factors to consider when choosing housing types

Decisions regarding housing types are influenced by a range of factors as highlighted in the previous section, including the type, setting and location of the development, socio-economic conditions, legal or town planning requirements or restrictions, topography, ecology and geotechnical conditions. In turn, the types of housing provided have an impact on the characteristics of the development with respect to, for instance, layout and structure, physical appearance, aesthetics, safety, security and density.

It is important to adopt a differentiated response with respect to the types of housing to be included in a development. This means that a range of housing types should ideally be accommodated in development projects to allow for some measure of individual choice.

The different housing options provided as part of a project would depend on a number of factors. In some cases, residents have the freedom to make significant decisions regarding their own residences and may have the opportunity to appoint architects and other professionals to help them create their ideal homes. In other cases, residents may be able to choose from a selection of standard house designs, or they could choose to live in cluster developments such as townhouse or apartment complexes and flats. Low-income developments, specifically subsidy-linked projects, require a particular way of dealing with housing type and choice, while informal settlement upgrading projects present their own set of challenges when it comes to housing decisions.

Some of the key factors to consider are briefly outlined in this section.

(i) Context-specific options

In general, the sensible approach is to, as far as possible, provide prospective residents with sufficient options to allow them to choose a house type that would adequately satisfy most of their needs. This is not always practical or feasible, but if it is realistically possible, a mix of housing types should be made available to meet the varying needs, requirements and aspirations of the intended residents. Some aspects that should be considered when deciding on the options that should be provided include the following:

- How can potential occupants with varying needs, e.g. children, the elderly, and people with disabilities, best be accommodated?
- Should space be allowed for vegetable gardens, backyard rental accommodation or an additional unit that can, for instance, be used as a granny flat, a home-based business or sub-let for an extra income?
- Is it feasible to incorporate retail space in a housing development, for instance on the ground floor of an apartment complex?

(ii) Density

Density is not an end in itself, but rather a means to an end. For instance, the reasons why relatively high population densities are required in certain areas are often to reach population thresholds that will ensure that a feasible public transport system can be operated in a particular area, to justify the provision of certain types of social facilities and amenities, or to justify investment in infrastructure. Similarly, the motivation behind medium (dwelling) density developments could be to reduce urban sprawl, to increase population densities so as to reach population thresholds, or to ensure the economic viability of a development project.

Various factors influence dwelling, occupancy or population density. (See **Section F.4.2.4** for more information on density measurement.) Housing type is one of the factors, but it is not the only determinant and it should be carefully considered together with other factors, taking into account the context of the relevant existing neighbourhood or planned development. It is important to remember that one specific house type could result in different densities, depending on building configuration and design, plot size, the layout of the neighbourhood and other factors.

Photo credit: Hannelie Coetzee (R) - www.brandsouthafrica.com

Figure H.2: Examples of housing types generally associated with low densities

In general, there is a relationship between housing types and dwelling (residential) densities, which is measured in dwelling units per hectare. Certain housing types, such as single detached (freestanding) housing, are usually associated with low densities, while attached housing such as walk-up apartments and townhouses are often described as medium-density housing (see Section H.3.3.2 for a description of housing types). Figures H.2 to H.4 illustrate this broad relationship between dwelling densities and housing types.

Housing types and dwelling densities

The numbers of dwelling units per hectare linked to low-, medium- and high-density levels differ according to country, city and local context. In South Africa, the description of low, medium and high dwelling densities vary (see Section F.4.2.4), but the following ranges are often used:

Low density: less than 40 du/ha (gross)
Medium density: 40 - 100 du/ha (gross)
High density: more than 100 du/ha (gross)

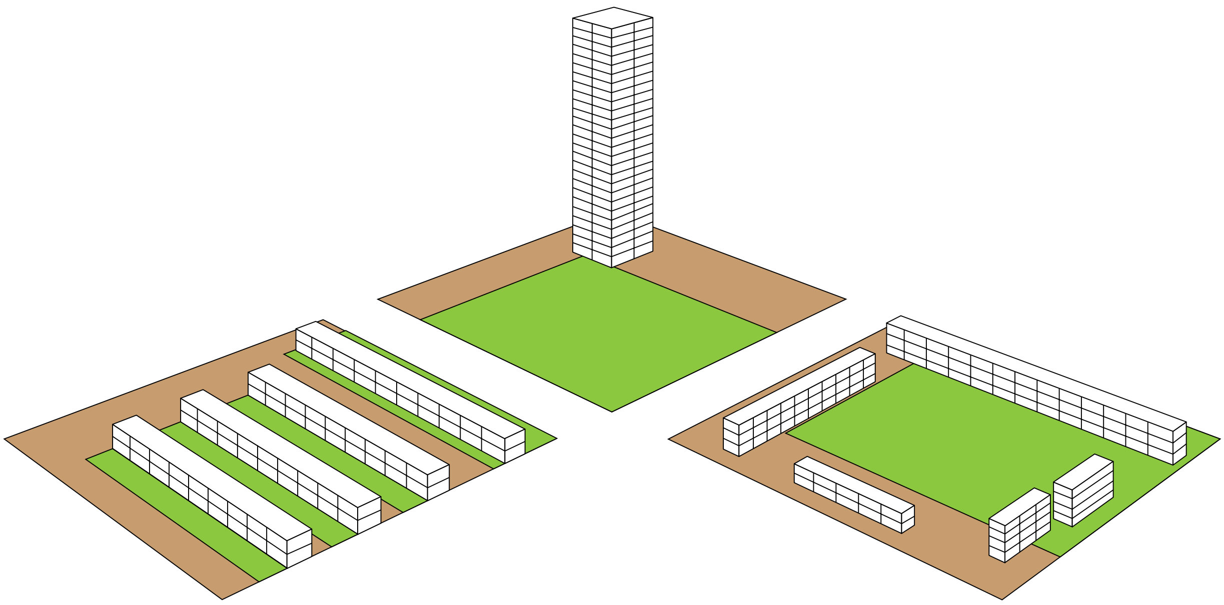
Photo credit: Chris Kirchhoff (T) - www.brandsouthafrica.com

Figure H.3: Examples of housing types generally associated with medium densities

Photo credit: Suzanne Loots

Figure H.4: Examples of housing types generally associated with high densities

Many factors can influence dwelling densities, and therefore different housing types may result in the same density depending on the way in which the dwelling units are configured. A housing development could take on different forms on a plot of a certain size and yet yield the same density, as demonstrated in Figure H.5. Aspects that could influence dwelling density in addition to the housing type include the design and size of the unit, shared spaces, circulation areas, gardens and parking spaces.



Three different types of housing with the same number of dwelling units per hectare.

Figure H.5: Different housing types could result in the same density

Housing types are, in principle, also linked to occupancy density (the number of people per unit). Certain housing types, such as single detached houses, can comfortably accommodate more people per unit than others, such as flats in a high-rise building. However, this is not always the case, and factors such as overcrowding may result in actual occupancy density levels that are higher than anticipated. For example, flats are sometimes occupied by more people than each unit was designed for, and small single dwellings (such as subsidised houses) may be occupied by more people than they were intended for. Conversely, some single dwellings may be occupied by only one or two people, even though they may be intended to house many more people.

Given the links between housing types and dwelling and occupancy density, it follows that there would also be a relationship between housing type and population density (the number of people per hectare). Certain housing types, such as blocks of flats, are more likely to result in higher population densities than detached dwellings. However, very high population densities are also often encountered in informal settlements due to overcrowding. In many cases, the informal dwellings are crammed close together and inhabited by far more people than they can comfortably accommodate (Figure H.6).

Figure H.6: Dwellings in informal settlements are often erected very close to each other, resulting in high densities

The types of housing included in a development will, to various degrees, influence the dwelling, occupancy and population densities that can be achieved. If a certain density needs to be achieved, the combination of housing types that should be provided has to be carefully considered. However, despite apparent correlations between density and housing type, it would be unwise to make assumptions without a clear understanding of the various other factors that could influence densities.

Dwelling and population densities do, and should, vary across different parts of a city or town. There is no ideal density that could be applied across a settlement. Certain densities are more suitable for particular land uses or types of neighbourhoods. For instance, activity or transport nodes, spines or corridors would require relatively high densities to ensure the infrastructure and services provided operate effectively and efficiently. Low-density development might be appropriate in areas where there are constraints such as topography, vegetation, character and heritage or where the installation of sewerage is restricted, requiring on-site wastewater disposal.

Decisions regarding densities and housing types should be guided by the context. Various factors should be considered, for instance:

- Low-density developments consisting of single detached houses on a plot may not contribute to the creation of more compact settlements, but in certain cases this type of housing may have to be provided to meet the needs of potential owners.
- Medium- to high-density housing such as three- to four-storey apartments or multi-storey flats may be appropriate in some cases, but they may not be suitable for families that need to utilise their dwellings for income-generating purposes such as informal businesses or the sub-letting of back-yard dwellings.
- Higher-density housing requires careful management and maintenance, otherwise it may increase the risk of overcrowding and could result in unsafe living conditions (Figure H.7).

Photo credit: Alexandra Renewal Project (R)

Figure H.7: Higher-density housing may increase the risk of overcrowding and could result in unsafe living conditions

An aspect that also plays a role when determining densities is known as the Floor Area Ratio (FAR). It refers to the relationship between the size of a particular plot and the floor area of all buildings on that stand. The ratio is calculated by dividing the gross floor area of all storeys of the buildings by the total area of the erf. The ratio is usually used by local authorities as a factor that determines the maximum floor area allowable on a particular plot in terms of a land use scheme. For instance, if a FAR of 0.5 is attributed to a site of 1 000m^2, the gross floor area allowable on the plot is calculated by multiplying the plot size by the factor, which in this case would be 500 m^2.

(iii) Tenure

In general, certain types of housing lend themselves better to a specific type of tenure than other types. For instance, single detached (freestanding) housing is suitable for rental, full title as well as sectional title ownership, while attached housing is usually associated with sectional title ownership or the social housing option.

When decisions are made about housing types to be included in a development, more than just the physical characteristics of the different types should be considered. Depending on the context, some tenure options may be more suitable than others. For instance, if the potential occupants of the housing to be provided are not expected to be able (or inclined) to purchase a property, housing types that would be suited to other tenure options such as rental should be made available. Often it would make sense to provide a range of housing types that would accommodate different tenure options to suit different levels of income and preferences.

(iv) Plot shape and size

Subdivision and housing type are interrelated, and therefore the housing types to be provided in a development would influence the shape and size of the residential stands as well as the layout and structuring of a development (see Section F.4.2.3).

> It is important to, if at all possible, first determine the types of housing to be provided and to then decide on the shape and size of the stands that would be needed to accommodate these housing types. The shape and size of the stands will also be influenced by other factors such as topography, so the process to decide on subdivision and housing type should be iterative.

(v) Character of the neighbourhood

The type of housing provided in a development plays a key role in defining the character of the neighbourhood and adjacent areas (Figure H.8). The design of the building, its positioning on the plot and its relationship with the street and open spaces and other buildings around it all contribute to the image of an area and the appearance of the local urban landscape in general (see Section H.4.2).

For instance, rows of detached or semi-detached houses could easily result in monotonous, impersonal and dreary neighbourhoods. Townhouse complexes, cluster developments and security villages often have the same effect on an area. In many cases, such developments are walled in, negatively affecting the quality of the streetscape and potentially creating unsafe areas for pedestrians. Such developments also reduce the permeability of certain parts of a settlement and inhibit the creation of integrated settlements.

Photo credit: Chris Kirchhoff (L); Graeme Williams (R) - www.brandsouthafrica.com

Figure H.8: Houses could be impersonal and dreary (L) or they could add character to a neighbourhood (R)

H.3.3.2 Housing typology

Housing typology involves the classification of housing into different types based on specific characteristics. The different types can be grouped together in a number of ways, but for the purpose of this Guide they have been categorised according to physical criteria as follows:

- Single detached housing
- Semi-detached housing
- Attached housing
- Flats/apartments

There is not always a clear distinction between the different categories of housing (Figure H.9). For instance, some of the characteristics of semi-detached and attached housing are sometimes combined, resulting in a hybrid housing type. Similarly, a building form that may be described as a walk-up by some people may be regarded as a block of flats by others. In practice, the four types manifest in various forms, permutations and combinations, as discussed in the following sections.

Figure H.9: The different categories of housing may manifest in various forms, permutations and combinations

(i) Single detached housing

Single detached, or freestanding, housing is found in medium to high-income suburban neighbourhoods as well as low-income developments (Figure H.10). Despite the apparent popularity of this housing type, it is also often criticised, for instance for not utilising land efficiently. It could include anything from a small, single-storey dwelling provided as part of a subsidy-linked development to a large multi-storey house on a lifestyle estate.

This type of housing is sometimes referred to as single family homes, but in reality they can be occupied by an extended family or even different families. It is also known as the 'one-house-on-one-plot' approach. However, a number of detached houses could also be grouped on a single large plot that used to have only one house on it. This type of development often takes place on large stands in established residential areas, increasing the neighbourhood density. The houses are freestanding units, but they usually have relatively small gardens and they share certain common areas, services and infrastructure. These developments are most often referred to as cluster developments, security villages or lifestyle estates, and the ownership mechanism could be full or sectional title.

Characteristics of single detached housing
• This housing type requires more land than most other types, thereby resulting in relatively low neighbourhood densities and contributing substantially to urban sprawl. • Providing municipal services infrastructure to this housing type is usually relatively expensive. • The surface area of external walls exposed to the external environment is relatively large, which could make it difficult to regulate the temperature inside the house. • The cost of maintaining a detached house may be relatively high and could place financial strain on the occupants. • The cost of building a freestanding house is relatively high. However, the cost per unit may be reduced in larger developments when the same house form is mass produced. • Single detached houses afford residents a substantial level of privacy and a sense of independence. • This type allows for outside living spaces, yards and garden areas, often all around the house, and often with a fair level of privacy. • Occupants of detached houses have direct contact with the natural ground level and usually have easy access to the street. • Detached houses normally allow for additions (extensions to the existing structure). • A single house on a plot often provides income generation possibilities, e.g. it may be able to accommodate a home-based enterprise. It may also allow space to build an extra room or flat on the property, or space for a vegetable garden, etc. • Owners have the freedom to personalise their homes as they wish and maintain it at a level that they can afford or prefer.

Photo credit: Cape Town Community Housing Company (T)

Figure H.10: Single detached houses

(ii) Semi-detached housing

Semi-detached housing refers to two adjoining houses, built on one stand, that share a communal wall (sometimes referred to as a party wall). The two units often mirror each other, and they can be single or double storey (Figure H.11). This type of housing usually has open space, or garden area, to the front, back and one side of the house.

This may not be the preferred housing type for some, precisely due to the fact that two units are connected by a communal wall. The garden or yard may also not be as private as some may want it to be. However, semi-detached housing does play a role in reducing urban sprawl, and it is a very suitable option to include in a low-income development. It is also a useful housing type for infill developments in more established neighbourhoods, where it is usually referred to as a duet.

Characteristics of semi-detached housing

- This housing type makes more efficient use of land and can be accommodated on smaller stands more effectively than detached housing. This type is usually associated with medium-density levels.
- Providing municipal services infrastructure to this housing type is generally less expensive compared to detached dwellings.
- The surface area of external walls exposed to the external environment is somewhat smaller than for detached dwellings, which could make it a bit easier to regulate the temperature inside the house.
- The cost of maintaining a semi-detached house is usually less than that of a comparable detached house.
- The cost of building a semi-detached house could be lower than that of a comparable freestanding house. As for detached housing, the cost per unit may be reduced in larger developments when the same house form is mass produced. If houses are provided on two floors, there could be further cost savings.
- Sound and fire proofing between two units may need special attention.
- Semi-detached houses afford residents a fair level of privacy and some sense of independence. The entrance door to each unit is separate, unlike with some forms of attached housing.
- This type allows for (usually semi-private) outside living spaces, yards and garden areas around the house, usually on three sides of the house.
- Occupants of semi-detached houses have direct contact with the natural ground level and usually have relatively easy access to the street.
- Semi-detached houses often allow for additions (extensions to the existing structure).
- This type of housing could provide income generation possibilities, e.g. it may accommodate a home-based enterprise, it may allow space to build an extra room or flat on the property, or space for a vegetable garden.
- Owners have some level of freedom to personalise their homes.

Photo credit: Cape Town Community Housing Company (T), City of Cape Town (B)

Figure H.11: Semi-detached houses

(iii) Attached housing

A row of more than two houses joined together by shared walls is known as attached housing. Units can be single or double storey (simplex or duplex). Two units could be built on top of each other; therefore the row of houses could be between one and four storeys high (Figure H.12).

Also known as row housing, attached housing can be configured in a number of ways and take on various forms. Row housing could be found in townhouse complexes where each unit will often have a parking space for a motor vehicle associated with it. Some attached housing developments are referred to as walk-ups. Walk-up apartment blocks are normally three to four storeys high, and each unit is directly accessible from the ground by means of a staircase. Attached housing could also be arranged around a semi-private courtyard (courtyard housing) or as small blocks of flats, sometimes referred to as maisonettes. Rental and social housing developments usually take on the form of attached housing.

Characteristics of attached housing

- This low-rise housing type makes very efficient use of land and can result in relatively high densities.
- Providing municipal services infrastructure to attached housing may in certain cases be less expensive compared to other housing types.
- The surface area of external walls exposed to the external environment is somewhat smaller than for detached and semi-detached dwellings, which could make it easier to regulate the temperature inside the house.
- The cost of maintaining some forms of attached housing could be less than that of comparable detached houses.
- The cost of building certain forms of attached housing could be lower than that of a comparable freestanding house. As for semi-detached housing, the cost per unit may be reduced in larger developments when the same house form is mass produced. If houses are provided on two floors, there could be further cost savings.
- Sound and fire proofing between units may need special attention. Noise from communal areas may be problematic.
- Attached houses afford residents lower levels of privacy and independence than offered by detached housing. The entrance door to each unit may be separate, but in some forms of attached housing an open walkway (gallery), landing or staircase may have to be shared.
- Private outside living spaces, yards and garden areas are limited. If a backyard is provided, the only access is usually through the house, which could be problematic. In some cases semi-private open spaces such as courtyards are provided, while individual units may have private balconies.
- Occupants of attached houses have some degree of direct contact with the natural ground level.
- Attached houses generally do not allow for additions (extensions to the existing structure).
- This type of housing does not normally provide ideal income generation possibilities within a unit, but it does allow opportunities for integrating commercial space into the residential development by, for instance, using the ground floor level of the building for retail or other types of businesses.
- Owners usually do not have much freedom to personalise external aspects of their units.

Photo credit: City of Cape Town (TR, MR)

Figure H.12: Attached houses

(iv) Flats/apartments

Blocks of flats or apartments are multi-storey buildings that are usually more than four storeys high (medium to high-rise developments). The building often has a central, shared entrance that provides access to corridors or walkways that connect the individual living units. The entrance doors to each flat, or apartment, could be located off a corridor (indoors passageway) or off a walkway (open gallery). A block of flats or apartments is usually serviced by one or more elevators, has shared open areas (e.g. for recreation, vegetation or washing lines), and may have parking spaces for motor vehicles on the ground floor, in the basement or elsewhere on the property (Figure H.13).

Characteristics of flats/apartments

- This housing type makes very efficient use of land and can result in fairly high densities.
- The cost of providing municipal services infrastructure to this type of housing would vary depending on the building height and other factors.
- The surface area of external walls exposed to the external environment could in some cases be considerably smaller than for other types of housing, which could make it easier to regulate the temperature inside the house.
- The cost of maintaining a flat or apartment would vary depending on the type of building, but it may be less than that of a comparable detached house.
- The cost of building this type of housing would depend on a number of factors, including the height of the building and the construction method.
- Sound and fire proofing between units may need special attention. Noise from communal areas may be problematic.
- Flats or apartments afford residents lower levels of privacy and independence than offered by detached housing. The entrance doors to different units may be separate, but they open up onto shared spaces such as corridors or walkways.
- Private outside living spaces, yards and garden areas are limited. Usually semi-private open spaces such as courtyards are provided, while individual units may have private balconies.
- The majority of those living in a block of flats or apartments do not have direct contact with the natural ground level.
- This type of housing does not allow for additions (extensions to the existing structure).
- It does not normally provide ideal income generation possibilities within a unit, but it does allow opportunities for integrating commercial space into the residential development by, for instance, using the ground floor level of the building for retail or other types of businesses.
- Owners usually do not have much freedom to personalise external aspects of their units.


Figure H.13: Flats

H.3.4 Social facility options

Social facilities contribute to the liveability of a neighbourhood by offering various services to those living in and around the neighbourhood. Most individual social facilities cannot be sustained by only one neighbourhood, and it is therefore important that facilities are placed throughout a settlement in such a way that they can be shared equitably by all residents. Not all facilities have to be in close proximity to all residents, but some, such as schools, health services and police stations need to be reasonably accessible to all communities. It is important that the locations of such facilities are chosen carefully. Some of the issues to consider are summarised below.

Decisions regarding the types and sizes of social facilities to be provided and their placing throughout a settlement should be carefully coordinated at a municipal level. At this level, a holistic view of the needs of an entire municipal area and the locations of existing facilities throughout the settlement is possible. This would assist in providing appropriate facilities in an efficient manner. For instance, it often makes sense to provide one large facility rather than a few smaller ones, and a municipality would have access to the information required to make this type of decision.

H.3.4.1 The equitable provision and distribution of social facilities

Various issues have to be considered when decisions have to be made regarding the provision of social facilities that would serve present and future needs. These issues include the availability and capacity of existing social facilities, the population thresholds required for viable social facilities, the distances that residents have to travel to reach social facilities, the cumulative demand for social facilities in the broader area, government's priorities for social service delivery and the demographic profile and specific needs of the community.

(i) Availability and capacity of existing social facilities

Residents use social facilities that are located within their own neighbourhood, in adjacent neighbourhoods or elsewhere in the settlement. Information on the number, capacity and location of existing social facilities in and around the proposed development has to be considered (see **Section H.3.2.4**). There might be no need for new facilities as there may be sufficient service capacity at existing facilities within an acceptable distance from the proposed development. It is also possible that some facilities (such as schools) are within reach of the proposed development, but that they are utilised at full capacity. The additional demand will then require the expansion of the existing facilities or the construction of new facilities. Another possibility may be that existing facilities are out of reach of the residents of the proposed development. This may require the construction of new facilities depending on whether there is sufficient cumulative demand in the area (see **Section H.3.4.1 (iii)**).

Fixed social facilities can be supported by a range of additional and complementary mobile, satellite, outreach and periodic services. This should be taken into consideration when assessing the availability and capacity of social facilities.

(ii) Population thresholds, access distances and population densities

Three inter-related aspects should be considered when making decisions regarding the size and distribution of social facilities, namely population thresholds, access distances and population densities. (see **Section F.4.2.4** for more information on density measurement.)

Population threshold refers to the size of the population that could be effectively served by a specific social facility. More specifically, the population threshold indicates the minimum number of people living in a specific area (catchment area) that would possibly necessitate (and be able to sustain) the provision of a particular social facility. Therefore, the population size of a proposed development is one of the factors that would influence decisions about the number, the size and the range of social facilities that may have to be provided.

Population thresholds differ depending on the type of social facility (see Tables H.1 to H.6). In general, facilities that are visited often by many people (e.g. schools) would have a lower population threshold than those that are visited less frequently but by more people (e.g. offices of the Department of Home Affairs). For all social facility types, the population threshold increases with the level of service specialisation provided by the facility. The reason for this is that the higher the level of specialisation, the less often community members are likely to visit the facility thus the bigger the size of the community needed to support it. For instance, a Primary Health Care clinic would be used regularly by many people, while few people will visit a more specialised facility such as a hospital on a regular basis.

A further aspect that needs to be considered is the access distance, which is the distance that people need to travel to reach a social facility. Access distances differ depending on the type of facility (see Tables H.1 to H.6). The area within the polygon created by these distances around a particular facility is regarded as the service catchment area. Population thresholds are directly linked to catchment areas, hence access distances are closely related to population thresholds. Access distances are influenced by a range of factors including the topography (e.g. flat or hilly terrain), street layout (e.g. permeable or impermeable for pedestrians), the availability of public transport, and the setting of the area (urban, peri-urban or rural). Social facilities that are accessed frequently by a large portion of the community should ideally be located relatively close to the target population to ensure short travelling distances and walkability for potential users of the service (refer to **Section F.4.2.2** for a discussion on walkable neighbourhoods).

Population density should also be considered when making decisions regarding the provision of social facilities. Population density refers to the number of people in an area (see **Section F.4.2.4** and **Section H.3.3.1 (ii)**). It has an impact on population thresholds and access distances and should influence the spatial distribution and size of social facilities.

Making decisions regarding the type, size and location of social facilities to be provided

Detailed information regarding population thresholds and access distances related to various types of social facilities is provided in the *CSIR Guidelines for the Provision of Social Facilities in South African Settlements.*[6]

The guidelines are supported by a web-based decision-making tool, the *CSIR Space Planner.*[7] Once a set of requirements (standards) for social facility provision has been agreed, this tool can be used to determine the impact of a specific development on the social facility demand and calculate the space requirements of the facilities. Impact estimates are calculated for the range of facilities to be provided as well as the size (capacity) of the different facilities and the land area required for the provision of the said social facilities.

For guidance on the application of differentiated social facility provision standards in non-metropolitan areas (delivering social services to rural areas), make use of the *Social Facility Provision Toolkit* [8] of the Department of Rural Development and Land Reform, which is populated with predefined facility standards. With this toolkit facility demand can be calculated for any population size or for 1 328 predefined regional service catchment areas in South Africa for which population statistics are provided.

(iii) Cumulative demand for social facilities

The service catchment areas of social facilities vary depending on the type of service provided. In some cases, the facility primarily serves the needs of those living in close proximity to the facility, but often a facility is also used by people who live in parts of the settlement that are quite a distance away. The calculation of demand for social facilities in a neighbourhood is therefore influenced by the cumulative demand and supply of social facilities for the whole settlement or an area that consists of a number of neighbourhoods. The demand created by one or more new (housing) projects (often spread across different neighbourhoods) should be added to the existing demand for social facilities (in the area surrounding the new development) to calculate the cumulative demand for the entire area. Where possible, neighbourhoods should be planned in a coordinated way so that each contributes equitably to the provision of land or facilities for social service delivery. This is best coordinated by the local municipality.

(iv) Government social service delivery priorities

The provision of social facilities is not regulated by a single government department or the responsibility of only one of the three spheres of government (national, provincial or local). It is therefore not always possible to identify specific government priorities that may assist in guiding decisions regarding the provision of social facilities as part of a development project. Consult domain-specific guidelines, policies, norms, standards or regulations of all the relevant government departments and their entities when making decisions regarding the provision of social facilities.

It is essential to involve relevant government departments from the outset when a development project is planned to ensure they are aware of the possible impact of the development on service delivery and to assist them with planning their services. For instance, it is important to collaborate with the South African Police Service (SAPS) to enable them to manage possible changes in crime patterns due to the addition of potential targets (people, property, etc.), locations (streets, parks, facilities, etc.), and even offenders. The development may place additional pressure on the existing resources of the local police station, and they need to be made aware of this as early on in the development process as possible.

(v) Demographic profile of the residents

Another aspect that might influence the provision of social facilities is the demographic profile of the residents of the area to be developed and of nearby neighbourhoods. Different groupings (e.g. retired people, families or single people) do not necessarily use the same social facilities with the same frequency. A clear understanding of the differentiated needs that exist will contribute to appropriate supply of services relative to the demand and lead to more informed provision and distribution of social facilities. However, the composition of the residents living in an area will change over time, with the demographic profile also likely to change. For instance, while it may be necessary to plan for an ECD centre in a neighbourhood when it is developed, this need may disappear as the community changes over time and the facility should be repurposed.

Socio-economic status and income levels also have an impact on the type and location of social facility provision. For instance, shorter travel distances to social facilities should be prioritised in lower-income areas, as residents often have to walk (costs may prohibit them from using private or public transport). Certain social facilities, e.g. Primary Health Care clinics respond directly to the needs of lower-income communities and will usually have to be accommodated in such developments. People with higher incomes may select to use social facilities provided by the private sector, even if these facilities are not conveniently located.

(vi) Community-specific needs

If the residents of a greenfield development are known, they could be included in the development process and could potentially inform decisions regarding the provision of social facilities (see **Section E**). The residents of neighbourhoods surrounding a proposed development could also provide useful information to guide decisions regarding social facilities. Information regarding social facility needs may also be included in the IDP.

H.3.4.2 Types of social facilities

The following social facilities typically require physical infrastructure at a neighbourhood level and land may have to be set aside or rezoned to accommodate them in some development projects:

- ECD centres (including day-care centres, nursery schools, play schools and after-school care facilities)
- ECD Resource Centres/ Hubs
- Primary schools
- Secondary schools
- Primary Health Care clinics
- Community Health Centres (CHCs)

- Libraries
- Community halls
- Multi-purpose centres
- Government departments' offices and/or service points (including Home Affairs offices, Labour centres, Social Development offices, SASSA offices, social grant pay points)
- Police stations
- Fire stations
- Homes for the aged
- Child and Youth Care Centres (CYCCs) (including children's homes)
- Post offices/ postal agencies/ post boxes
- ICT access hubs/ Information centres

Tables H.1 to **H.7** provide brief descriptions of each of these facilities and give a broad indication of typical population thresholds and access distances. A range of population thresholds is presented to allow for adjustments in facility sizes, contexts (urban, rural, peri-urban), different settlement types and other issues.

Some government departments provide specific guidance on relevant facilities, e.g. the Department of Sport and Recreation's *Norms and Standards for Sport and Recreation Infrastructure Provision and Management*[9] and the Department of Basic Education's *National Minimum Uniform Norms and Standards for School Infrastructure*[10]. More detail is also provided in the *CSIR Guidelines for the Provision of Social Facilities in South African Settlements* and the Department of Rural Development and Land Reform's *Social Facility Provision Toolkit*[11] (see **Section H.3.4.1(ii)**). Guidelines for the provision and location of social facilities should always be considered within the context of the development project. The provision of public open spaces in neighbourhoods is discussed in **Section G**.

Table H.1: Population thresholds and access distances for typical facilities offering education services

Social facility type	Typical population threshold (number of people)	Ideal maximum access distance (km)
Early Childhood Development centres (including day-care centres, nursery schools, play schools and after-school care facilities). These facilities provide programmes for the care of more than six and less than 150 children younger than five years of age.	2 400 - 3 500	2 - 5
Early Childhood Development Resource Centres/ Hubs Large ECD facilities are equipped for the care and development of children younger than five years of age. They also provide outreach services to the community and surrounding smaller facilities, and act as a training and resource centre with respect to other ECD facilities and programmes in the community.	20 000	5

Table H.1: Population thresholds and access distances for typical facilities offering education services

Social facility type	Typical population threshold (number of people)	Ideal maximum access distance (km)
Primary schools Primary schools are education facilities for Grades R to 7 (age group 5 to 12). Three categories of school sizes (small, medium and large) are used for different contexts. Small schools (with a minimum population threshold of 1 000 people) should only be used in cases where no other options are available. Grade R classes should ideally form part of a primary school but can also be provided at a pre-school facility or be accommodated in a stand-alone facility.	2 200 - 6 600	5
Secondary schools Secondary schools are education facilities for Grades 8 to 12 (age group 13 to 17). Three categories of school sizes (small, medium and large) are used for different contexts. Small schools (with a minimum population threshold of 2 000) should only be used in cases where no other options are available.	4 000 - 10 000	5

Table H.2: Population thresholds and access distances for typical facilities offering health services

Social facility type	Typical population threshold (number of people)	Ideal maximum access distance (km)
Primary Health Care clinics Primary Health Care clinics are permanent facilities (public or private) at which a range of primary health care services are provided, for at least eight hours per day and four days per week.	5 000 - 60 000	5 - 10
Community Health Centres (CHCs) CHCs are appropriately equipped permanent facilities that offer a broad range of primary health care services including observation beds, accident and emergency services, midwifery services, but not surgery under general anaesthesia. These facilities are operational 24 hours a day and seven days a week.	60 000 - 150 000	10

Table H.3: Population thresholds and access distances for typical facilities offering community services		
Social facility type	**Typical population threshold (number of people)**	**Ideal maximum access distance (km)**
Libraries Public libraries of different sizes and grades provide resources and services to meet the needs of the general public for education, information and personal development. These facilities usually have study areas, meeting rooms, and may provide the public with access to computers and the internet.	Basic: 5 000 - 25 000 Branch: 50 000 - 150 000	Basic: 5 Branch: 10
Community halls Community halls (Grades B to E[12]) are used for community activities such as public meetings, training and entertainment events. The halls usually have kitchens, toilet facilities and storage space. The size (and the available facilities) of halls can vary considerably. In sparsely populated areas halls are sometimes used as a venue from where periodic services can be provided e.g. pension pay-outs, mobile clinic services and periodic home affairs and other e-government services.	5 000 - 60 000	8 - 10 (urban) 10 - 30 (rural)

Table H.4: Population thresholds and access distances for typical facilities offering civic services		
Social facility type	**Typical population threshold (number of people)**	**Ideal maximum access distance (km)**
Multi-purpose centres These public service centres are 'one-stop' service centres where communities can access a multitude of government services and other community services. Typical services provided include SASSA offices, Home Affairs offices, Labour offices and police stations.	20 000 - 200 000	15 (urban) 25 (rural)
Government departments' offices Government departments (national and provincial) often provide local branches or service delivery points where the public can access department-specific services or information. These offices are often part of public service centres or may be part of a periodic mobile e-government outreach service. The following departments or agencies are typically establishing local facilities for this purpose:		
Department of Home Affairs offices **Department of Labour offices**	20 000 - 200 000	15 (urban) 25 (rural)
Department of Social Development offices	5 000 - 40 000	15 (urban) 25 (rural)
SASSA offices (for registration and administration of grants)	30 000 - 120 000	15 (urban) 40 (rural)

Table H.4: Population thresholds and access distances for typical facilities offering civic services

Social facility type	Typical population threshold (number of people)	Ideal maximum access distance (km)
Social grant pay points Social grant pay points are locations at which cash payments of various forms of social grants are made to grant recipients. No specific land requirement is necessary for these facilities and payments are often made from post offices, banks and supermarkets. Where a non-electronic cash service is still provided this is often at community halls or part of public service centres. These facilities should allow for the additional space requirements that accompany the payment of grants each month, e.g. the possibility of people queuing on certain days (provide toilets and seating) and for informal trading taking place in close vicinity.	200 or more grant recipients	5

Table H.5: Population thresholds and access distances for typical facilities offering security and emergency services

Social facility type	Typical population threshold (number of people)	Ideal maximum access distance (km)
Police stations Police stations are buildings that accommodate police officers and other members of staff of the South African Police Service (SAPS) and may also accommodate the Metro police. These facilities usually contain offices, temporary holding cells and interview rooms and may provide living quarters for personnel on site.	10 000 - 60 000 dependent on context and crime rates	≤ 8 (urban) 24 (rural, but dependent on context and crime rates)
Fire stations Fire stations are facilities where firefighters are stationed and where fire-fighting apparatus (vehicles and other equipment) are stored. These facilities may include limited dormitory facilities and work areas such as meeting rooms, workshops, practical training areas, gymnasiums, etc.	Context-dependent	The response times for fire stations are specified in *SANS 10090:2003 Edition 3*. It ranges from 8 minutes for high-risk land uses (including informal settlements) and CBD areas to 13 minutes for conventional brick residential areas and 23 minutes for rural areas.

Table H.6: Population thresholds and access distances for typical facilities offering social services		
Social facility type	**Typical population threshold (number of people)**	**Ideal maximum access distance (km)**
Homes for the aged These facilities provide housing for the aged and may incorporate frail care and nursing facilities. Their provision is not required by law.	20 000 - 60 000	25
Child and Youth Care Centres (CYCCs) A CYCC is a facility that provides residential care for more than six children not living with their biological families. Examples include children's homes, places of safety, secure care centres, schools of industry, reformatories and shelters for street children. The population threshold and access distance indicated here are only applicable to children's homes.	20 000 - 60 000 for children's homes	25 for children's homes

Table H.7: Population thresholds and access distances for typical facilities offering communication services		
Social facility type	**Typical population threshold (number of people)**	**Ideal maximum access distance (km)**
Post offices/ postal agencies/ post boxes Service delivery facilities where the public can access post office services and information. No specific land requirement is necessary and facilities are commonly rented within retail facilities.	10 000 - 20 000	5 - 10
ICT access hubs/ Information centres A facility that provides community access to information and communication technologies (ICT), including internet access, computers and telephones. These facilities are often supported by free wifi hotspots at public facilities.	5 000	5

Privately owned commercial facilities such as shopping malls and petrol service stations often provide social services to the public, for example public toilets and gathering spaces. These privately owned facilities provide services that complement those delivered in social facilities operated by government. This role should be acknowledged where appropriate, and taken into consideration when making decisions regarding the provision of social facilities operated by government.

H.4 Design considerations

This section outlines the factors that need to be considered when incorporating housing and social facilities into the design of a development. It is closely linked to Section F.4 that deals with the design of the street and plot layout of a neighbourhood.

When designing and constructing housing and social facilities, it is important to remember that buildings need to adhere to some or all of the following regulations, norms and standards:

- All buildings have to be designed and constructed in accordance with the National Building Regulations, applied in accordance with *SANS 10400*.
- As stipulated in the Housing Consumers Protection Measures Act, 1998, all home builders must be registered with the National Homebuilders Registration Council (NHBRC). In addition, every home should be registered with the NHBRC before construction commences.
- Stand-alone houses provided in terms of the National Housing Programmes should be designed and constructed in accordance with the National Norms and Standards as approved by the Minister of Human Settlements.[13]

H.4.1 Locating housing and social facilities in a neighbourhood

Where appropriate, neighbourhoods should be developed to incorporate a mix of land uses, income levels, and housing types. Such mixed neighbourhoods would usually result in medium densities and allow a range of housing options that potential residents can choose from (Figure H.14).

Figure H.14: A mix of land uses and housing types

If possible, locate medium to higher-density residential and retail buildings along higher-order, or 'main' streets (Figure H.15). Social facilities should be located to be accessible to their service populations. Social facilities that serve a broader community (and have a higher population threshold), or that are likely to outlive the current community usage, should be "externalised" in the sense that they should be located on the edges of the neighbourhood or at places where they can be accessed with relative ease from surrounding neighbourhoods. See Section F.4.5 for a discussion on the planning of social facilities as part of the neighbourhood layout and structure.

As far as possible, concentrate social facilities at central locations together with other public facilities, amenities and service points adjacent to public spaces (e.g. squares, transport facilities or parks) to create clusters or service precincts. The clustering of social facilities is discussed in Section H.4.4.

Figure H.15: Locate medium to higher-density residential and retail buildings along higher-order streets

H.4.2 The relationship between buildings and the street

The relationship between buildings and the street play a key role in determining the character of the street. The nature of the boundary and the interaction between the building and the street or sidewalk could contribute to the creation of vibrant, active neighbourhoods. Houses and townhouse and security complexes surrounded by high walls, often incorporating electric fences, could create sterile neighbourhoods (Figure H.16). Alternative perimeter protection measures could be considered, such as fences that allow visual contact between the building and the street (Figure H.17). This allows for passive surveillance, which could reduce opportunities for crime (see Section O.1).

Figure H.16: Walls limit visual contact between houses and the street, potentially increasing opportunities for crime

Figure H.17: See-through fences and street-facing buildings allow for visual contact between buildings and the street

H.4.3 The placement of buildings on a plot

Siting refers to the location of a building on a plot, and to its relationship with adjacent properties and to the street. Where appropriate, buildings should be sited in such a way that it is possible to extend the building without too much difficulty should this be required at some stage. In particular, freestanding houses should be positioned such that additional rooms could be added as the need arises. The location of a building on a plot plays a key role in the relationship between buildings and the street (Figure H.18). Issues to consider include the interaction between the building and the sidewalk, and the treatment of the boundary and any walls or fences (see Section H.4.2).

Photo credit: Cape Town Community Housing Company (R)

Figure H.18: Placement of houses close to the street could contribute to the creation of an interesting streetscape

H.4.4 Clustering of social facilities

The clustering of social facilities can potentially be more convenient to users of the different facilities. By heading for a single destination, users of multiple facilities can save on travel time and cost. These clusters also become nodes and structuring elements within a neighbourhood (see **Section F.4.4**).

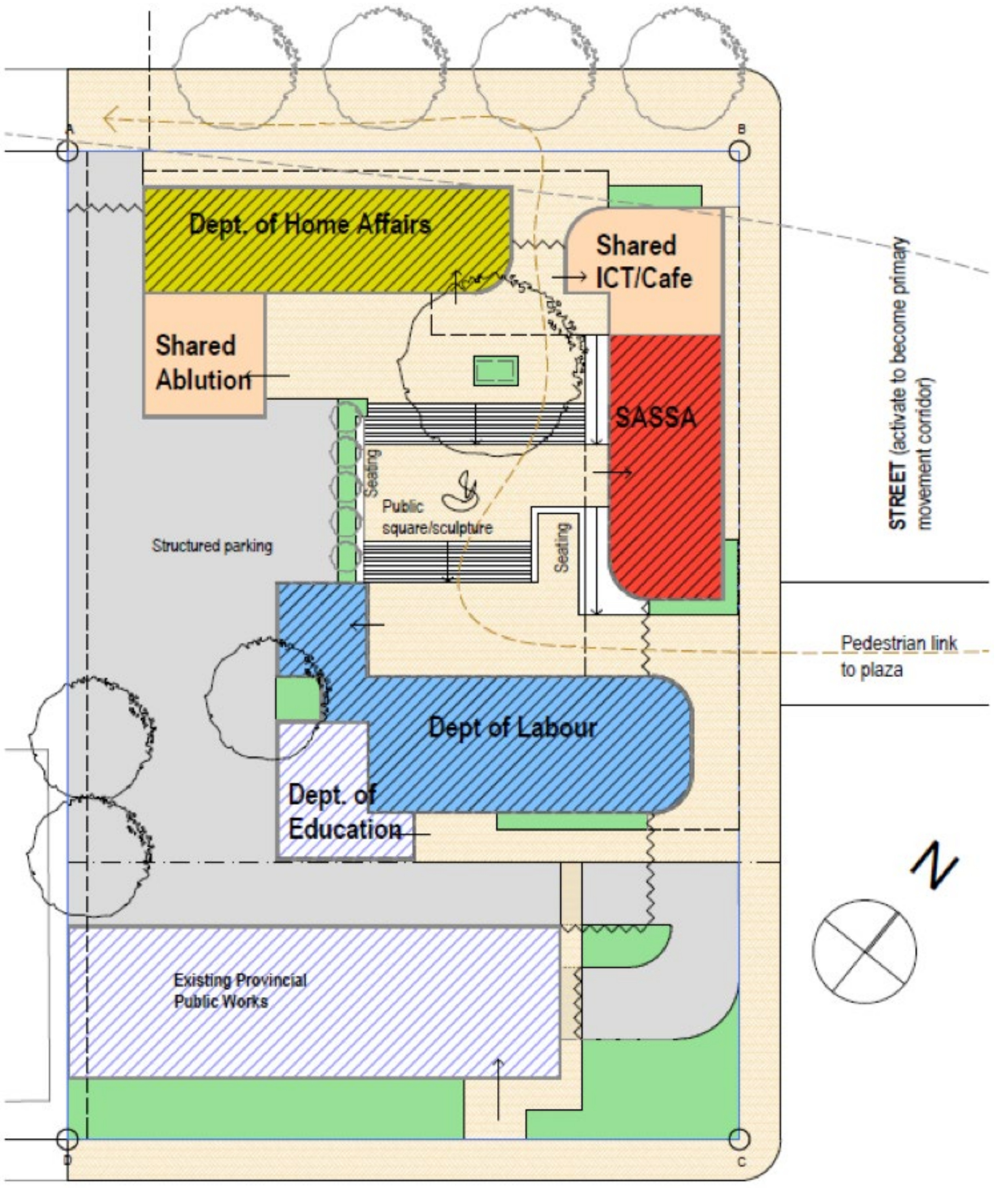
The clustering or grouping of different social facilities at accessible and central locations can improve the viability of the individual facilities and may have a number of financial benefits:

- If land has to be purchased and rights to build have to be secured (through for example a rezoning or a township establishment), the costs can be shared between different facilities.
- Certain elements of the social facilities can potentially be shared (e.g. waiting areas, public toilets, parking or cafeteria facilities). However, the nature of the different social facilities should be considered beforehand to ensure that these arrangements are workable and can be managed by the different entities. For instance, experience has shown that the waiting areas of health facilities should ideally not be shared with other facilities' waiting areas.
- Construction costs might be lower and even the land area required for the cluster may be less.
- Running costs of the different facilities that can potentially be shared include ICT services and infrastructure, administrative and secretarial staff and services, maintenance staff and services and security staff, services and installations. This would, however, require efficient and effective organisational and financial management to ensure that operational processes and responsibilities are clearly understood by all.

Complementary types of social facilities that could be grouped together include the following:

- ECD centre, primary school, library, recreational facilities
- Primary school, secondary school, library, community hall
- Fire station, police station, victim support centre, clinic

Key anchor facilities that could be included in a cluster include different offices of certain government departments (e.g. Home Affairs, Labour, and Social Development). Other facilities that could form part of these multi-purpose centres include pension pay points, clinics, libraries and ICT access hubs. These facilities can also be combined with public transport stops and open space such as public squares, parks and playgrounds.



Credit: Department of Public Works

Figure H.19: Clustering of social facilities - government precinct

Glossary, acronyms, abbreviations

Glossary

Access distance
The maximum distance that people should have to travel to reach a facility.

Building line
An imaginary line that defines an area within and parallel to the boundary of a plot within which no permanent structures may be built. The purpose of the building line is to prevent buildings from being erected too close to neighbouring properties or to the street. Building lines are defined in the local land use scheme and are not the same for all plots.

Consent use
Consent use means that a municipality allows additional land use rights on a particular property upon request. The zoning of the property will not be changed. The zoning category, as described in the land use scheme, usually makes provision for a pre-described number of uses that may be allowed for with the necessary consent.

Desire line
An imaginary line that links facilities or places, forming a convenient and direct route for pedestrians and cyclists. Desire lines become evident when watching people move through an area. These lines are often visible as informal footpaths across open space.

Land use scheme
A land use scheme forms part of a land use management system that regulates and manages land use within a municipality. The scheme confers legal rights to properties to develop and to erect and use buildings subject to certain stipulated conditions. A detailed description of the content of a land use scheme is provided in Chapter 5 of SPLUMA.

Plot
A measured piece of land, also known as an erf, stand or site that is registered at the deeds registration office or forms part of a municipal land use scheme.

Population threshold
The size of the population that could be served effectively by a specific facility. More specifically, the population threshold indicates the minimum number of people living in a specific area (the service catchment area) that would possibly necessitate (and be able to sustain) the provision of a particular facility.

Rezoning
A colloquial description of the process of making an amendment to a land use scheme (or any of its provisions), to change the land use rights and development restrictions applicable to a specific property.[14]

Servitude

A servitude is a registered right that a person or an entity has over the immovable property of another person. It usually means that a portion of land is set aside for a specific purpose, such as road widening, or provision for engineering infrastructure (e.g. water pipelines, electricity cables, sewerage pipes). The municipality might for example have the right to construct electricity cables over a privately owned property. The property owner is then restricted in what he or she can do within the servitude. The servitude is attached to the property and will continue to exist even if ownership of the land changes. The servitude forms part of the conditions contained in the title deed and can only be cancelled by agreement between both parties.

Site development plan

A plan that provides an overview of the intended development on a property, specifically indicating features such as the position of the proposed buildings, access provisions, parking, landscaping, adherence to the building lines and the position of servitudes.

Township establishment

Township establishment is a legal process whereby agricultural land is converted into proclaimed individual plots (with certain land use rights attached to them), which can be transferred to different owners. The process is regulated by SPLUMA.

Zoning

A property's zoning stipulates the purpose for which the land may be used and is described in the municipality's land use scheme. The zoning also stipulates restrictions on the building erected on the property in terms of floor area ratio, coverage, density, parking requirements, etc. In order to change the purpose for which the property can be used, an application for rezoning has to be submitted to the local municipality for consideration.

Acronyms and abbreviations

CBA	Critical Biodiversity Area
CBD	Central Business District
CHC	Community Health Centre
CSOS	Community Schemes Ombud Service
CYCC	Child and Youth Care Centre
DORA	Division of Revenue Act
ECD	Early Childhood Development
ESA	Ecological Support Area
FAR	Floor Area Ratio
FET	Further Education and Training
HLAMDA	Home Loan and Mortgage Disclosure Act
ICT	Information and Communication Technology
IDP	Integrated Development Plan
NBR	National Building Regulations
NGO	Non-Governmental Organisation
NHBRC	National Home Builders Registration Council
NMT	Non-Motorised Transport
SABS	South African Bureau of Standards
SANBI	South African National Biodiversity Institute
SAPS	South African Police Service
SASSA	South African Social Security Agency
SPLUMA	Spatial Planning and Land Use Management Act
TOD	Transport-Oriented Development

Endnotes

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Section I
Transportation and road pavements

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 I

Transportation and road pavements

The Neighbourhood Planning and Design Guide

Table of contents

I.1 Outline of this section

I.1.1 Purpose

Settlements are integrated systems in which the various components are interconnected, and this section highlights the role of transportation in this system. Transportation (mobility and access) significantly affects the quality of living environments; therefore the aspects addressed in this section play an essential role in achieving the vision for human settlements outlined in **Section B**.

This section deals with the planning and design of roads and streets that are able to accommodate a range of transport options, including non-motorised transport (NMT), public transport and motor vehicles. Aspects that should be taken into consideration when establishing the transportation demand created by a neighbourhood development are outlined, and information regarding the related infrastructure options available is provided. Guidance is provided with respect to geometric design as well as the structural design of road pavements. For the purposes of this Guide, 'road pavement' refers to the surface material of a road (incorporating all the associated layers). 'Road' refers to any pathway (road or street) that is intended to accommodate and facilitate the movement of pedestrians, cyclists, animal-drawn carts, wheelchairs, motor cycles, motor vehicles, etc., as well as other activities that may take place in neighbourhood streets.

Section I links directly with **Section F** (Neighbourhood layout and structure), **Section G** (Public open space), **Section L** (Stormwater) and **Section O.2** (Universal design), and care should be taken to ensure that the information provided in all these sections are considered when applying the guidelines provided in any of the three sections.

I.1.2 Content and structure

This section (Section I) is structured to support effective decision-making related to transportation and road pavements. The decision-making framework is outlined in Figure I.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 transportation and road pavements 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 transportation and road pavements 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 transportation and road pavements that are available for consideration

Design considerations

Guidelines to assist with the design of transportation 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 I.

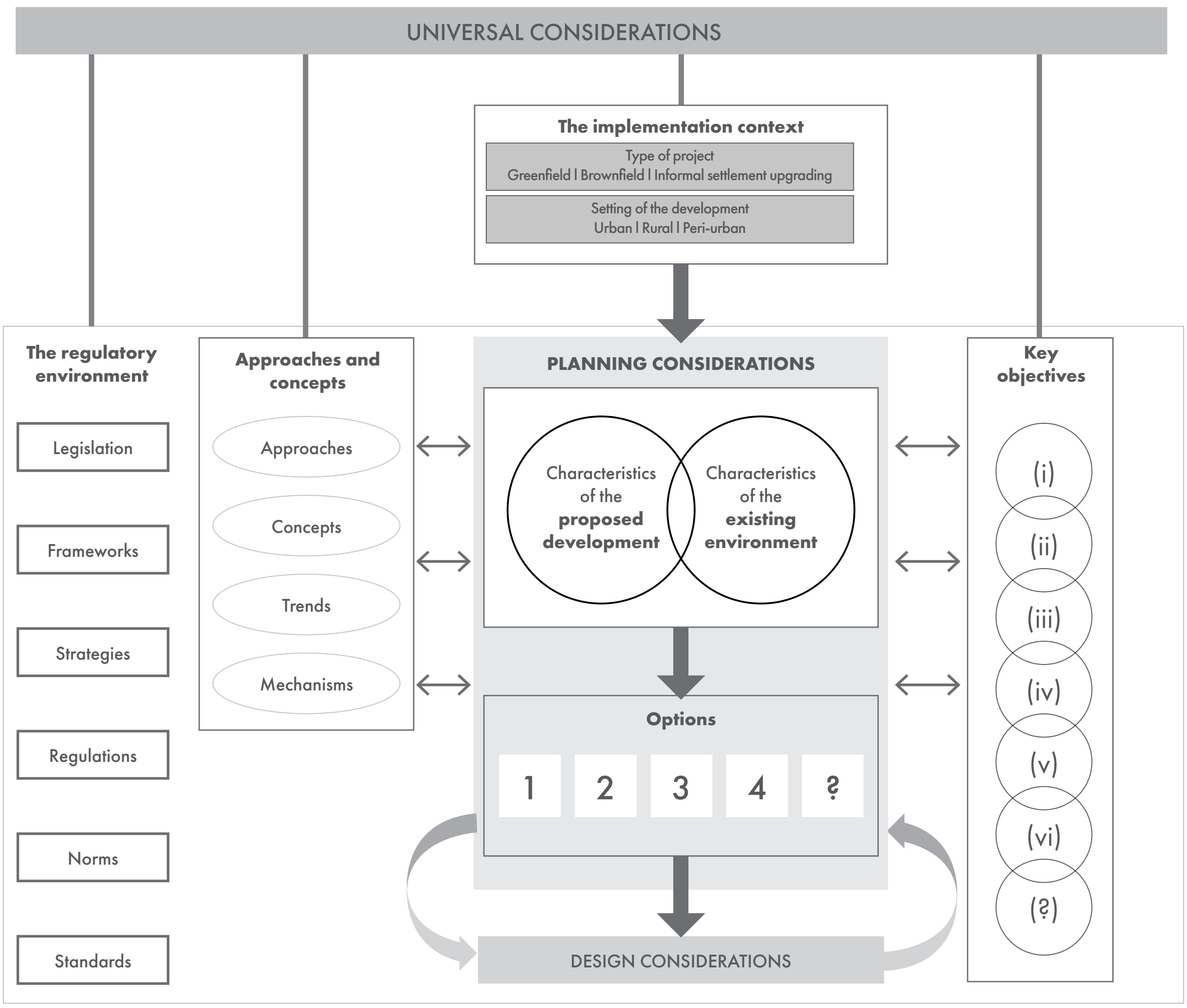


Figure I.1: A framework to assist with planning and design decisions

I.2 Universal considerations

I.2.1 The regulatory environment

A range of legislation, policies and strategies guide the planning and design of transportation facilities and services for human settlements. Legislation and policy that have direct implications for neighbourhood transportation planning and design are briefly outlined below. They are not discussed in detail, so it is important to consult the relevant documentation before commencing with any neighbourhood development project.

(i) Policies, plans, frameworks and strategies

A number of policies, plans, strategies and frameworks guide various aspects of transportation and related infrastructure planning and investment in South Africa, including the following:

- National Land Transport Strategic Framework 2006
- Road Infrastructure Strategic Framework for South Africa (RISFSA) 2006
- Rural Transport Strategy of South Africa 2007
- Public Transport Strategy and Action Plan 2007 (which made provision for the introduction of Integrated Rapid Public Transport Service Networks)
- National Non-Motorised Transport Policy 2012
- National Learner Transport Policy 2015
- National Transport Master Plan (NATMAP) 2016
- Draft Green Transport Strategy (2017-2050)
- Draft Revised White Paper on National Transport Policy 2017
- Draft National Road Safety Strategy (2016-2030)

Provincial Land Transport Frameworks, developed in terms of the National Land Transportation Act, inform the transportation policy environment in the various provinces. At a local level, municipal planning mechanisms include long-term development visions and city development strategies, Comprehensive Integrated Transport Plans, the Integrated Development Plan (IDP) sector plans (including Spatial Development Frameworks) and, in the case of certain municipalities, the Built Environment Performance Plans (BEPPs). Some national government departments have guidelines aimed at the local level, such as the National Treasury's Urban Network Strategy toolkit, which provides guidance for transportation planning. There are also municipal by-laws that require adherence to traffic and transportation planning and design guidelines and specifications.

(ii) Legislation

The National Land Transport Act (NLTA) of 2009 (with amendments) governs all urban and rural land transport planning in South Africa. It specifies the legal responsibilities of the different spheres of government and deals with the application of national principles, guidelines, norms and standards. Some of the aspects addressed in this act that should specifically be considered when implementing Section I of the Guide, include the following:

- All municipalities have to develop Comprehensive Integrated Transport Plans (CITPs). In addition to ensuring proper intermodal planning and coordination of transportation between adjacent municipalities and between different spheres of government, these CITPs must be accommodated in and form an essential part of municipal IDPs, as required by the Municipal Systems Act of 2000.

- Local land transport planning must be integrated with the land development and land use planning processes in the municipality.
- Municipalities must plan for and actively encourage the optimal use of available travel modes and specifically promote public transport by, for instance, implementing and managing modally integrated public transport networks (IPTN) and travel corridors.
- Any substantial change or intensification of land use on any property may be subject to traffic impact assessments, public transport assessments and universal access audits as required by national, provincial and municipal transport authorities.

Other pieces of legislation pertaining to road transport infrastructure include the National Road Traffic Act of 1996, the South African National Roads Agency Limited and National Roads Act of 1998, as well as provincial acts.

Legislation that is not sector-specific, but has to be considered in the planning and design of transportation infrastructure and services at a neighbourhood level, includes the National Building Regulations and Building Standards Act of 1977 (and amendments), the National Environmental Management Act of 1998 and the National Heritage Resources Act of 1999.

(iii) Guidelines, manuals and standards

To give effect to legislative requirements and policy provisions, a range of guidelines, manuals and other documents are available to assist with neighbourhood transportation planning and design. At a national level, the Department of Transport's publications include the Non-Motorised Transport (NMT) Facility Guidelines 2015 and the South African Road Safety Manual (SARSM), which is under the custodianship of the Road Traffic Management Corporation (RTMC). The South African Road Traffic Signs Manual 2012 (SARTSM) is an important guideline document for all road traffic signs, including the signing requirements at various intersection types and guidelines for the design of traffic signal systems at intersections (Volume 3).

The Technical Methods for Highways (TMH) or Technical Recommendations for Highways (TRH) series of publications are compiled under the auspices of the Roads Coordinating Body (RCB) of the Committee of Transport Officials (COTO) and published by the Department of Transport. The TRH guides provide information about current, recommended practice in selected aspects of road engineering, based on proven South African experience. The TMH manuals prescribe methods that can be used in various road design and construction procedures. Both sets of documents are relevant to roads in general, not just highways, as the titles may suggest. They address a range of topics, dealing with, for instance, traffic impact assessments (TMH 16), trip data parameters (TMH 17), road classification (TRH 26) and the use of road reserves (TRH 27).

SANRAL also publishes the South African Pavement Engineering Manual (SAPEM), which is a best-practice guideline covering a range of elements of pavement engineering. The South African Bitumen Association (SABITA) publishes a number of technical manuals, covering the selection, handling and use of bituminous materials for road construction.

Publications relevant to universal access (as it applies to transportation) include SANS 10400-S: 2011 (Facilities for Persons with Disabilities), SANS 784: 2008 (Design for access and mobility - Tactile indicators) and National Technical Requirement 1: Pedestrian Crossings (NTR1 2016), developed by the Department of Transport.

Municipalities often have their own guidelines and design standards on issues related to transport planning, non-motorised transport, traffic safety, parking provision, the provision of transport infrastructure in informal settlements, geometric standards and the like.

I.2.2 Key objectives

Objectives related to transportation have been formulated in various transport policy and planning publications. Increasingly, the focus is shifting towards improving access and mobility for all, regardless of the mode of transport used. Furthermore, there is a growing recognition that all users should be accommodated, including those with disabilities. The planning and design information contained in this Guide aims to support this and advocates the development of transportation infrastructure that caters not only for motor vehicles, but purposefully also accommodates pedestrians, cyclists, wheelchairs, etc. In addition to facilitating movement by means of various forms of transport, neighbourhood streets should also support a range of social, economic and recreational activities (See **Section F.4.1**).

The vision of the National Transport Master Plan (NATMAP) 2016 [1]

An integrated, smart and efficient transport system supporting a thriving economy that promotes sustainable economic growth, supports a healthier lifestyle, provides safe and accessible mobility options, socially includes all communities and preserves the environment.

A number of objectives have been identified to direct the planning and designing of neighbourhood transportation infrastructure. Transportation infrastructure should meet the following requirements:

- Improve access and mobility for all users
- Enhance the safety and security of all users
- Minimise negative impacts on the environment
- Support economic activities
- Respond to the needs of all users
- Be reliable and of an acceptable quality

(i) Improve access and mobility for all

In essence, the purpose of transport is to allow people and goods to move from one place to another. Inherent to this are two aspects, namely access and mobility. Transportation infrastructure should allow people to access their destination with relative ease, and to travel between two places within a reasonable time. Internationally, access and mobility are described in various ways, and different definitions are presented.

For the purposes of this Guide, access is interpreted as the ability to reach and utilise a particular destination. Destinations such as facilities, services, activities and opportunities are accessible if they can be approached and entered with ease by all people, including pedestrians, cyclists, people with disabilities, and those who are dependent on public transport. Access, or accessibility, can be improved in a number of ways. For instance, the accessibility of a particular destination is enhanced if it can be reached by means of a range of motorised and non-motorised transport options, and also if the time to reach destinations is reduced as a result of their location within a neighbourhood. If a number of facilities such as a clinic, gymnasium, library and shops are grouped conveniently in a neighbourhood, it may make them more accessible to the community.

Access and mobility

Access has to do with the question "where can I go?" It relates to the ability to reach and utilise a place, but not the act or process of moving.

Mobility has to do with the question "how can I get there?" It relates to the ability to move from one place to the other.

Mobility is the ability of people and goods to move between two places, and the ease with which this can be done, regardless of the mode of transport. Mobility can be improved by providing safe and efficient infrastructure to accommodate all modes of transport, including non-motorised options. When interventions to improve mobility are planned and designed, the needs of all people, including pedestrians, cyclists, people with disabilities, and those who are dependent on public transport, should be acknowledged.

Access and mobility are interrelated. Good mobility in a neighbourhood, whether by means of motorised or non-motorised transport, could potentially improve accessibility. However, the destinations that people want to access need to be located in or near the neighbourhood. Similarly, desirable destinations may be provided, but it may be difficult to reach them due to a lack of good quality roads, pedestrian walkways, or public transport facilities.

In some cases, such as in a rural setting, access is, to a large degree, dependent on mobility. Due to the distances between, say a residential and a shopping area, effective and safe mobility infrastructure is required to allow people to access a specific destination. In other cases, accessibility may be reduced as a result of the infrastructure provided to increase vehicular mobility. Access by pedestrians or cyclists to for instance a shopping centre may be compromised as a result of busy multi-lane streets and a lack of safe pedestrian crossings and inadequate or no infrastructure to accommodate taxis and other public transport services. Access to favoured destinations could also be reduced if these destinations are located alongside a street designed to accommodate fast-travelling vehicular traffic.

(ii) Enhance safety and security

All the components of transportation infrastructure should be planned and designed such that the risk of any user being injured or killed in an accident, or of being a victim of crime, is reduced. All users should be considered, including people with disabilities, and regardless of age. Whether people are walking, cycling, using a wheelchair or mobility scooter, travelling by motor vehicle, making use of public transport, or any other mode of motorised or non-motorised, they should be and feel safe and secure.

Aspects that should be considered to reduce physical injuries and fatalities as a result of any type of accident include, for instance, the design of pedestrian crossings, walkways and cycle lanes, the type of material used to pave streets and walkways, the type and positioning of lighting, the timing of traffic signals etc. (Section I.3.3). Geometric design (Section I.4) also plays an important role in creating streets that are safe for the users of motorised as well as non-motorised transport modes. Aspects such as the location and spacing of intersections, lane widths, horizontal curvature radii and sight distances could play an important role in creating a safe transport environment for all.

When developing transportation infrastructure, opportunities for crime can be reduced by applying the principles of crime prevention through environmental design (CPTED) (Section O.1). Furthermore, by applying CPTED strategies, safer spaces can be created that would decrease people's feelings of insecurity. It is important to ensure that the security of all users – regardless of their mode of transport – is considered. This means that all pedestrians, cyclists and other users of non-motorised transport, as well as motorists and users of public transport should be provided with a safe and secure environment.

(iii) Minimise environmental impact

The emphasis on improving accessibility and mobility through fossil-fuelled transportation systems has come at a price, namely an escalation in harmful atmospheric emissions and the associated negative impact on the natural environment. Other negative effects of car-based transportation systems include noise pollution, the consumption of productive land and landscape damage resulting from the provision of transportation infrastructure.

One way of significantly reducing the negative impact of transportation on the environment is to lessen people's dependence on fossil-fuelled private motor vehicles as a mode of transport. At a settlement level, this would require the commitment and active involvement of various role players. A number of strategies need to be in place and a range of services be provided to encourage people to make use of alternative forms of transport. For instance, to reduce people's reliance on private transport, an effective, efficient, safe, reliable and affordable public transport system is essential. More importantly in the South African context, however, is the need to accommodate people making use of non-motorised transport, particularly those who have to walk or cycle almost everywhere they need to go to.

When applying the guidelines provided in Sections I.3, I.4 and I.5, the possibility of promoting the use of non-motorised transport by planning and designing suitable infrastructure should be a guiding factor when making decisions. For instance, wherever possible, infrastructure should be provided at a neighbourhood level to support pedestrians, cyclists and users of other modes of non-motorised transport. The use of non-motorised transport could be accommodated (and encouraged) by for instance providing dedicated, safe cycle lanes and pedestrian walkways, designing safe pedestrian crossings, etc.

Another aspect to consider when making decisions aimed at reducing the impact of transportation infrastructure on the environment relates to the pavement material used. Certain materials and construction methods are more environmentally friendly than others, and it is therefore important to consider all factors before making a decision regarding the technology to be used.

(iv) Support economic activities

Access to transport (and a lack thereof) plays a critical role in the extent to which people are able to participate in economic activities. For instance, transport allows people to travel to and from their places of employment, it enables job seekers to search for employment opportunities and to attend job interviews, it connects businesses to each other (e.g. to deliver services and goods) and it allows customers and clients to interact commercially with a range of businesses.

Effective and efficient transport infrastructure supports job creation and economic activity, and it is essential for growth and development. Since a large proportion of the South African population does not have access to private motor vehicles, there is a particular need for infrastructure that accommodates and supports public transport and non-motorised transport. Many people have to cycle, walk and/or make use of public transport to participate in economic activities. Without appropriate infrastructure and an effective, efficient, safe, reliable and affordable public transport system, their ability to partake in and contribute to the economy, whether formal or informal, is severely compromised.

(v) Accommodate the needs of all users

Neighbourhood transportation infrastructure and services should, as far as possible, accommodate the needs of all potential users. The aim should be to provide universally accessible transport that could be used with ease by all, including people with disabilities, elderly people, children, pregnant women, etc. (See **Section O.2**.)

Streets should meet the needs of people, not just of motor vehicles. This means that streets should be designed to enable the movement not only of motor vehicles, but also non-motorised modes of transport. Wherever appropriate, streets should allow for a range of activities to be integrated, including leisure, trading and recreation. In some communities, streets provide the space for social interaction, and this should be acknowledged in the street design. (See **Section F.4.1**.)

Safe streets and walkways should be provided that would purposely support walking and cycling. Not only are these the only modes of transport available to many people, but if the infrastructure is provided, it may encourage others to walk and cycle, which would contribute to improving their health and wellbeing. At a neighbourhood level, pedestrians should be prioritised by incorporating pedestrian desire lines when deciding on a street layout pattern, providing safe pedestrian crossings and employing traffic calming measures.

It is always expedient to provide transport infrastructure that would allow people with a choice when they need to travel. Infrastructure should be designed to allow for changes that may occur over time. Even if there is a focus on accommodating pedestrians, it should not necessarily be assumed that certain communities do not have access to motor vehicles based on economic or other criteria. (See **Section O.2**.)

(vi) Ensure quality and reliability

Good quality, reliable transportation infrastructure, as well as proper management and operation practices, are essential for achieving the majority of the other objectives discussed here. People depend on the infrastructure to travel to, for instance, healthcare and education services, recreational facilities, to do shopping and to participate in employment activities. Importantly, they need the infrastructure to be regularly maintained so as to allow them to be safe and secure when they travel, and to be universally accessible. Well-maintained infrastructure would have less harmful effects on the environment than ineffective, inefficient infrastructure.

It is therefore critical to ensure that the infrastructure is carefully planned and designed according to appropriate standards. Factors that could improve operation processes and procedures and reduce the need for constant maintenance should be considered when design decisions are made. This would assist in ensuring that the infrastructure remains effective, efficient and reliable. The use of innovative technologies should be incorporated where appropriate to improve the quality of the infrastructure and to support mechanisms implemented to improve reliability.

I.2.3 Approaches and concepts

This section briefly summarises possible approaches, strategies and mechanisms that could be utilised, or local or international concepts, ideas and trends that could be implemented to achieve the objectives discussed in **Section I.2.2**.

I.2.3.1 Classification of the road and street system

The classification of the road and street system has implications for all aspects of transportation planning and design. *TRH26: South African Road Classification and Access Management Manual*[2] outlines a rural and urban road classification system that consists of six classes (see Table I.1). In this system, roads are classified exclusively on the basis of their function. The fact that a road has been built or managed to a particular standard does not mean that it has a particular function. Functional and not geometric or condition criteria are used for classifying roads. The appropriate hierarchy of the multi-functional street at a local level should be determined by the local needs and the context of the site, and not by simply applying a guideline. (**Section F.4**.)

Table I.1: The South African road classification system (Based on TRH26)

Class	Function	Description	Urban		Rural	
			Design speed (km/h)	Typical road reserve width (m)	Design speed (km/h)	Typical road reserve width (m)
Class 1	Mobility	Principal arterial	120	60	120	62
Class 2		Major arterial	80	40	120	48
Class 3		Minor arterial	70	30*	100-120	30
Class 4a	Access/ activity	Collector street: major	60	25	80-100	25
Class 4b		Collector street: minor	50	20	80-100	
Class 5a		Local street: commercial	40	22	60-80	20
Class 5b		Local street: residential	40	14**	60-80	
Class 6		Walkway	n/a	n/a	n/a	n/a

* Reserve up to 62m is required to allow for Bus Rapid Transit (BRT).
** Reserve of 10.5m is typical if street is less than 100 m long.

Road classification plays an important role when making decisions regarding aspects related to accessibility and mobility, intersection spacing and control, public transport infrastructure provision, and the balance required between different road types to structure an efficient network. Several of these issues are addressed in *TMH 16 South African Traffic Impact and Site Traffic Assessment Standards and Requirements Manual* (2014).

According to TRH26, public transport systems have their own classification system, ranging from strategic public transport routes (SPTR), integrated rapid transit (IRT), bus rapid transit (BRT) and high occupancy vehicle (HOV) priority lanes, to local distribution routes and termini. In neighbourhoods, most public transport routes, and possibly even strategic bus routes, will be on access/activity streets where pedestrian facilities and bus stops are mostly found.

I.2.3.2 Transport demand management

Transportation demand management (sometimes referred to as travel demand management, traffic demand management or mobility management) refers to the application of different strategies to reduce the demand for travel or to redistribute the demand for travel in space and/or in time.

The overall aim of travel demand management is to increase the efficiency of a transportation system by giving priority to travel based on the value and cost of each trip. Higher-value trips and lower-cost modes are prioritised through a number of interventions. For example, buses are regarded as having higher value to the system (they transfer more people per trip) and should thus receive priority over private vehicles. Public transport, ridesharing, cycling and walking generally cost society less per trip than low occupancy private cars when considering roadway costs, congestion, harmful emissions and traffic accidents, and they should therefore receive priority over private vehicles.

The management of the demand for transport can include a number of interventions that have a cumulative impact on the efficiency of the system and ultimately improve the liveability of settlements. Some of these interventions are aimed at improving transport options available to users, while others provide users with incentives to change routes, modes, destinations or the schedule of their trips. Also included in transport demand management are interventions that reduce the need for physical travel such as improved internet-based communication systems.

I.2.3.3 Transport-oriented Development

Transport-oriented Development (TOD) refers to the concentration of a mix of medium- to high-density, pedestrian-friendly developments around or close to public transport stops, terminals and stations. The intention of this approach is to reduce the need to use motorised modes by making trips walkable, to improve access to public transport and reduce commuting time. Importantly, by increasing the concentration of people in the immediate vicinity of the transport stop, the necessary passenger demand thresholds for public transport can be achieved.

Transport-oriented developments are site-specific and dependent on the proximity of public transport stops, terminals and stations. For such developments to be successful, streets should be safe and convenient for all, including pedestrians, cyclists and people with disabilities. The developments should incorporate a mix of land uses including residential, retail, recreational and entertainment.

I.2.3.4 Complete streets

Complete streets are streets for people, not just cars. The concept is based on the notion that, under certain conditions, the entire road reserve should be regarded as public open space and should be planned, designed, operated and maintained to accommodate all users safely and conveniently. This means that everyone should feel comfortable using the street, regardless of their age and mode of transport, including pedestrians, cyclists, wheelchair users, motorists, public transport users, etc.

The approach is aimed at neighbourhood streets, and its application in practice would be determined by the local context. Complete streets don't all look the same, but they could typically include the following elements:

- Pedestrian and cycling infrastructure such as walkways, bicycle lanes, bicycle storage facilities, public furniture, landscaping, frequent and safe street crossing opportunities, kerb extensions, etc.
- Bus lanes and comfortable and accessible public transportation stops
- Appropriate traffic-calming measures to enable safe access and use of the street as social space

I.2.3.5 Non-Motorised Transport

Non-Motorised Transport (NMT) refers to all forms of transport that are not motorised, including walking, cycling, animal-drawn transport, cycle rickshaws, skateboards, hand carts and wheelchairs. For shorter distances, NMT is usually the most efficient means of transport, but its use is influenced by land use, topography, travel needs and the layout of infrastructure and services. The planning and design of NMT infrastructure and services have received attention through theoretical concepts such as complete streets (**Section I.2.3.4**) and by promoting the adoption of a 'pedestrian first' hierarchy of users (**Section F.4.1.3**). More information is available in the *Non-Motorised Transport (NMT) Facility Guidelines* published by the Department of Transport.[3]

I.2.4 The implementation context

This section highlights the contextual factors that should be considered when making decisions regarding transportation infrastructure, specifically related to the type of development and its setting. Also refer to **Section D.2.1** (Type of development) and **Section D.2.2** (The setting/location of the planned development).

I.2.4.1 The type of development

(i) Greenfield development

There are usually no or little formal (motorised) transport activities directly on a greenfield site. However, in urban and peri-urban settings there is likely to be transport activity in the surrounding area. This transport activity may have to be quantified as part of the transport inventory. In addition, the transport road network and public transport services and infrastructure in the areas around and through the project site will also have an impact on the transport planning and design of the greenfield project. An important issue to consider when doing street layout planning for a greenfield site is the presence of desire lines, where pedestrians crossing the site show their preferred routes even in the absence of formal transportation infrastructure.

(ii) Brownfield development

Brownfield developments occur at sites where there is current land use and transport activity associated with the site. Transportation infrastructure may be located on the site and may be used as is or be in need of improvement and upgrading. If the project entails infill development or redevelopment, many of the existing land use activities and associated trips may remain, and the trips may even increase. The development of brownfield sites often implies higher population densities, which will have direct implications for the type and capacity of transportation infrastructure.

(iii) Informal settlement upgrading

Informal settlement upgrading projects are usually complex undertakings that require extensive community participation. Acceptability and perceptions may be important factors to consider when making decisions regarding transportation options. Space is usually limited in informal settlements and developments are often done in situ. An in-situ layout involves creating spaces between existing top structures for the purposes of access as well as installing pipes and cables for infrastructure services. This would require the existing movement tracks, pathways and desire lines through the informal settlement to be identified and mapped before layout proposals are made. In an informal settlement upgrading project, the provision of NMT infrastructure will be an important aspect to consider.

I.2.4.2 The setting of the development

(i) Rural

Development sites in rural areas will vary in nature depending on the location, for instance whether it is situated in a rural town or a dispersed settlement. Rural settlements do not show the strong weekday morning and afternoon trip peaks found in urban areas, therefore the infrastructure design requirements are likely to be different, even though the transport planning process is the same as for peri-urban and urban areas. Public transport service provision is an important aspect of planning in rural areas, although it might be with low trip demand and low frequency services. There is a general lack of adequate NMT infrastructure in rural areas, which needs to be addressed as NMT users in rural areas not only include pedestrians and cyclists, but also animal-powered vehicles.

(ii) Peri-urban

Peri-urban areas often serve a dormitory function and mostly lack the investment to drive employment growth that will require their inhabitants to travel long distances to access employment opportunities, social services and education. This strong functional relationship with adjacent urban settlements requires an efficient transportation system. However, peri-urban areas are sometimes neglected in the planning and design of transportation infrastructure and services. Quite often, municipal public transport systems only operate within the 'urban' areas of settlements and residents of peri-urban areas are mostly dependent on private motor vehicles, provincial bus services or unregulated public transport such as mini-bus taxis.

(iii) Urban

Congestion is one of the prevalent transport problems in large urban areas. This aspect is strongly related to long commuting times and harmful environmental impacts of the transportation system, especially through the use of private cars. In urban areas typical weekday morning and afternoon public and private transport trip peaks are associated with existing land uses in the area. The public transport passenger demand drops dramatically in the off-peak periods, resulting in unused system capacity. With the high rate of urbanisation, the capacity of transportation systems in the peak periods remains an issue, while low-density development poses challenges related to transportation network coverage. The structural design of pavements generally does not differ between urban and rural contexts, except in the selection and design of the surfacing layer and drainage.

I.3 Planning considerations

This section deals with the planning of transportation infrastructure. In this context, the term "planning" means making informed decisions regarding the type of transportation infrastructure to be provided, and then choosing the most appropriate options based on a thorough understanding of the context within which the planned development will be implemented.

As part of the planning process, it is important to consider the neighbourhood layout and structure (refer to Chapter F) while also considering the type of project, the potential residents of the neighbourhood and the transportation trips, modes and network distribution. The features and requirements of the proposed project should always respond to the context within which the planned development will take place (Section I.3.2). The planning phase is concluded by considering different transportation options (Section I.3.3), specifically related to geometric design and then road pavements.

The transportation planning process starts with the definition of the study area, which is the area to be included in the transportation study. It is unlikely to be just the boundaries of the new project or neighbourhood. Transportation and traffic impacts can occur remotely from the development site. The careful definition of the study area ensures that a detailed understanding of the regional and local context of the project is developed, including the scale; the urban, rural or peri-urban nature of the study area; the socio-demographic status of the inhabitants; existing transport infrastructure and services; and other planned and existing developments in the area.

I.3.1 Characteristics of the proposed development

Decisions regarding transportation infrastructure and services 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. Factors that should be considered are discussed below.

I.3.1.1 The nature of the proposed development

Various factors related to the nature of a development could influence decisions regarding the provision of transportation facilities and services. For instance, an extensive transportation master plan could be required for large neighbourhood development schemes. This is unlikely to be the case for smaller developments and improvement schemes for existing streets that are likely to be less complex, and, in some cases, a scheme layout is generally all that is required. Smaller projects may also not require detailed transportation design, as existing infrastructure might have spare capacity available. In these cases, the focus of the transportation planning would be to link into and integrate with existing systems. Large (or mega) projects may have to consider a range of transportation modes and require the inclusion of various public transport and NMT facilities. For mobility and access design purposes, population density and land use mix are critical considerations, as the efficiency of public transport facilities and services are dependent on user thresholds. Mixed use (i.e. a mix of residential and other land use types), mixed-income projects and projects that are primarily residential in nature would also need different approaches to the provision of transportation infrastructure and services. 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 clearly understood to make informed decisions regarding appropriate transportation options and facility and service provision.

I.3.1.2 The residents of the area to be developed

Decisions related to the mode of transport and its capacity and coverage should be guided by information regarding the potential residents and users of the planned infrastructure and services. Traveller needs could be informed by various attributes of the neighbourhood inhabitants, including incomes, trip patterns for all modes to and from the neighbourhood, public transport dependence, car ownership levels and the needs of disabled persons. Usually, the detailed socio-economic characteristics of the residents of the new development are not known when a development is planned and designed. It can also be difficult to predict who and how many residents will make use of transportation infrastructure and services. However, it may be possible to make assumptions regarding the possible nature of the future residents and users of transportation by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to consider the following:

- The total number of residents that would have to be accommodated, taking into consideration that actual numbers may be higher than anticipated due to the fact that the provision of houses and services may attract more people than originally planned for.
- The number of households and the types of housing to be provided in the development. This will have an impact on the transport demand and influence the modes used.
- The range of residents with special needs that would have to be accommodated, e.g. people living with disabilities, including physical, dexterity and sensory impairment. Transportation infrastructure and services should, as far as possible, be accessible to all residents and users.
- The age of residents and those that may use transportation facilities (i.e. gender ratios, age profile and size). An aging population might, for example, increase the number of public transport users who might require easier access to vehicles. Trip patterns might also differ (in terms of timing or destination) between the youth and the elderly. Other dimensions have been shown to influence travel choices such as gender, and occupation, which may be used for even finer segmentation of the beneficiaries.
- Income and employment levels and spending patterns might give an indication of car ownership or dependence on public transport.
- The number and location of schools, social and recreational facilities and retail facilities to be provided in the neighbourhood. This will inform the number of trips generated and the distribution of trips along the movement network. This will also give an indication of the opportunities for transport-oriented development.

As discussed in **Section F**, layout and transportation planning should apply a user hierarchy where pedestrians are considered first. Most residents start and/or end their trips using an NMT mode. They therefore require the opportunity to use safe, direct and secure NMT routes to their destinations. The premise of this approach is that, if the most vulnerable user of the system is provided for first, provision for the rest (cyclists, public transport users, specialist vehicles like ambulances and finally, ordinary motor vehicles) will be far easier. This will also lead to a design that increases the attractiveness of walking, cycling and using public transport.

I.3.2 Characteristics of the existing environment

Decisions regarding transportation infrastructure and services need to be guided by an assessment of the context within which the development will be located. Factors that should be considered are discussed below.

I.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the project site could influence the transportation infrastructure and service to be provided.

(i) Topography

The topography of the project site is a key factor when making decisions regarding the direction, hierarchy and layout of the roads and streets. A site that is characterised by slopes has a significant impact on the provision of municipal engineering services, especially stormwater management. It could also affect the provision of NMT facilities, as the gradient should ideally not be more than 5% for pedestrian and cycle routes. Gradients also affect stopping distances that have to be provided for motorised vehicles, as well as road pavement design and appropriate road surfacing.

In addition, the structural design of roads may also be influenced by topography: where roads and streets cross height contours at an angle, or even perpendicularly, drainage design becomes a challenge and in such cases function rather than structure may require that a road or street be paved or provided with effective erosion protection. A sloping site could mean that additional costs would have to be incurred when constructing a street. The maximum gradient for the use of road surface asphalt paving is 14%. Streets that are steeper than this might have to opt for block or concrete pavement with accompanying support beams.

Topography also affects unpaved streets: In rolling and mountainous terrain there may be steep gradients that result in the erosion of street gravel and, in particular, erosion of their drainage facilities, with direct implications for their safety and functional use. A gradient of 5% is an average value above which erosion problems may occur on unpaved streets, and slopes steeper than this would warrant additional attention and protection. Gravels in the upper range of the Plasticity Index (PI) could effectively reduce erosion, but local conditions should be considered in the detailed evaluation.

> Water drainage is an important factor to consider when assessing the topography of a development site. Water is one of the primary causes of premature failure, accelerated distress and reduced structural capacity of road infrastructure, and it is therefore essential that attention be paid to stormwater management from the outset (see Section L).

(ii) Climate

Climate has an impact on the structural design of road pavements. The meteorological environment is divided into macro-climatic regions with different moisture and temperature conditions. The moisture condition affects the weathering of rock and the durability of weathered material. The moisture conditions also affect the stability of unbound layers, depending on the drainage conditions, the surfacing layer integrity and the moisture content. On the other hand, temperature conditions largely affect the design of surfacing layers, particularly hot mix asphalt. Pavement designers should always consider climatic conditions and avoid using materials that are excessively water-susceptible or temperature-sensitive in adverse conditions.

(iii) Geotechnical characteristics

The in-situ 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 might not be suitable for construction. A proper preliminary soil survey should be conducted as the characteristics of the underlying subgrade will have implications for the structural design of the road. The specific considerations regarding the subgrade are discussed in Section I.4.2.5.

Aspects such as the material depth and the classification of the subgrade material are addressed. However, the following questions need to be answered during the initial analyses of the local conditions to inform the layout and network configuration of the proposed development as well as the subsequent geometric and structural design phases:

- What are the soil characteristics and quality? Classification of the subgrade material should be done.
- Are there any aggressive chemicals or minerals present?
- Is the site part of or close to a dolomitic area?
- Was the site used for mining and exploration in the past?
- Are there large rock outcrops on the site?
- Are there gullies or other ditches on the site?
- Is ground water present on the site?
- What is the height of the water table?
- Did dumping – legal or illegal – ever occur on the site?
- Is the site subject to seasonal flooding?

(iv) Landscape and ecology

The physical features of the landscape could have an impact on the layout of streets and the choice of pavement material. If the development is located in or near an ecologically sensitive area, there may be restrictions that may influence the layout of streets. Ensure that information is collected regarding 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 approvals from various government departments.
- Wetlands, surface water bodies or other ecologically sensitive areas on or near the site.
- 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.

(v) Adjacent land uses and edge conditions

Adjoining properties have an impact on each other. Therefore, it is important to be aware of the land uses adjacent to the development site, as well as the edge conditions that affect the site. Some of the questions that need to be answered include the following:

- What are the adjacent land uses and how could that potentially influence decisions regarding transportation infrastructure to be provided as part of the proposed development? In particular, surrounding land uses are relevant for public transport planning.
- What are the local destinations (such as shops, schools, bus stops) that occupants of the new project will be wanting to access?
- How can the new development best be linked to these to encourage walking and cycling?

(vi) Access to the site

Any development has to be connected to the surrounding area and to the settlement as a whole. The layout of streets and the provision of transportation facilities are influenced by the location of access points and existing footpaths and routes. The following questions need to be answered:

- What are the existing and potential vehicular, cycle and pedestrian access points to the site?
- Are there existing footpaths / routes across the site? Where are these routes originating from and where are they going?
- Can the existing footpaths / routes be accommodated in the new development?
- Where are public transport facilities in the surrounding areas located in relation to the site? These may include commuter railway stations and services and other public transport facilities such as bus and mini-bus taxi terminals and stops.
- Are there existing public transport routes through or near the site? Where do these routes intersect or join with the pedestrian desire lines and the shortcuts that people take?

I.3.2.2 Available infrastructure and services

Developments create additional demand for services and may therefore have an impact on existing transportation infrastructure and systems. It may be necessary to document and assess the existing transportation infrastructure and public transport networks and services, including NMT facilities. This information can be used as the starting point for the planning and design of new networks and facilities, or the upgrading of existing infrastructure and services.

The location of existing public transport infrastructure such as stops, terminals and ranks should be documented. Public transport operations and routes should also be identified. For example, information regarding rail services, train station locations and feeder services, bus and minibus taxi services and main routes, BRT routes and stations should be collected. Existing NMT facilities must also be identified and assessed. These may be formal and/or informal, for example to and from existing public transport facilities, at schools, hospitals and other social and commercial amenities.

I.3.2.3 Existing socio-economic features

The planning and design of a development have to be guided by the potential needs of the residents of both the new development and existing neighbourhoods. If the community that will move into the proposed development is known, it is critical to understand their needs and involve them in the decision-making process from the outset (see Section E). It is also important to acquire information regarding the socio-economic features of the neighbouring communities. This will provide some indication of the transportation infrastructure and services that have to be provided. 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 age profile of the residents?
- What is the income profile of the residents?
- What is the employment profile of the residents?
- What types of housing are people living in?
- Do residents have access to private cars?

I.3.3 Transportation infrastructure and road pavement options

The design of transportation infrastructure and services should cater for the travelling needs of individuals and the need for products to be conveyed. Transport users generally make decisions about destination, mode of travel, departure time, desired arrival time and route. The decisions take place within constraints that include budgets and the availability of supporting services and infrastructure in the network. It is important to provide prospective users of a transportation system with sufficient options to allow them to choose an option that would adequately satisfy most of their needs. However, when transportation planners and designers have to make decisions regarding the type, capacity, coverage and cost of transportation infrastructure, the needs of individuals have to be balanced with the needs of society. A critical consideration would be the potential impact of a chosen transportation option on the environment. In addition, the structural design of transportation infrastructure tends to be guided by restrictions imposed on it by geology, topography, design traffic, construction materials, and accessibility and mobility requirements.

The transportation infrastructure and road pavement options discussed below essentially involve the geometric design of streets, and the types of road surfaces and pavement materials available. However, before particular options can be selected, various factors need to be considered. Some of these factors are outlined below before the possible options are discussed.

I.3.3.1 Factors to consider when choosing transportation and road pavement options

In addition to the aspects highlighted in **Section I.3.1** and **Section I.3.2**, various other factors need to be considered when decisions have to be made regarding transportation demand, needs and infrastructure options. Assessments may be required to gain an understanding of, for instance, the following:

- The estimated number and nature of trips that will be generated by the proposed neighbourhood
- The nature of existing traffic in the area surrounding the proposed neighbourhood
- Planned developments, land-use changes and transportation infrastructure and services in the vicinity of the proposed neighbourhood

Based on the information gathered, the anticipated trip demand can be assigned to the transportation network. These aspects are briefly discussed below.

The estimated number and nature of trips generated by the proposed neighbourhood

Three distinct trip generation estimations need to be made, namely vehicle-based trips, public transport trips, and non-motorised trips. Estimates are usually based on traffic expected during a chosen peak hour or peak time. Traditionally, the morning weekday peak hour is used since this is normally the time period during which the highest number of person trips are made, and hence needs to be accommodated by the infrastructure. However, other factors may also have to be considered. There may be conditions peculiar to the development site, which may result in other forms of peaks, for instance travel may change seasonally due to holiday-makers visiting the area or leaving the area, or if special events are held in or close to the neighbourhood.

The information required to estimate trip generation includes the following:

- The socio-demographic and economic characteristics of the neighbourhood. This information often provides an indication of the number, pattern and modes used for trip making.
- The number of households, their location in the neighbourhood, and the type of housing that is to be supplied will have an impact on the transport demand and influence the modes used.
- Traffic generators including education facilities, hospitals and clinics, shopping/retail areas, transport terminals (road-based, rail and airports) generate and attract high concentrations of trips and should be treated individually.
- Land use types such as commercial, office or retail facilities may also generate particular trip patterns.

- Specific developments that could reduce motor vehicle trip making, such as transport-oriented developments.

A distinction should be made between trips that will have origins and destinations within the neighbourhood (e.g. trips made between home and school), trips that will be made from the neighbourhood to other destinations in the settlement (e.g. trips from home to work), and trips that may pass through the neighbourhood. In some cases it may also be important to gain an understanding of the distribution of trips according to purpose and the mode of transport (i.e. NMT and motorised trips, as well as the split between public and private transport). This will assist in planning services and infrastructure that will meet the transportation needs of those living in and around the proposed neighbourhood, particularly with respect to NMT.

The nature of existing traffic in the area surrounding the proposed neighbourhood

The estimated number of trips that the proposed neighbourhood will add to current motor vehicle traffic should be considered in conjunction with the existing traffic situation ('background traffic') and transportation demand. The 'background traffic' refers to traffic demand that would have materialised irrespective of the development project under consideration. The annual rate of growth of this demand should be taken into consideration.

In some cases a detailed quantification of the existing transportation demand may be required (including vehicular traffic, NMT and public transport). Some of the data required may be available from local, provincial and national transport authorities and transport agencies. However, it may be necessary to conduct transport surveys to supplement the demand data available from secondary transport data sources. The need for surveys, and the types of surveys required, would be determined by the availability of secondary data sources, the context and size of the proposed development, and whether or not transport simulation modelling will be required. Different types of traffic surveys can be employed, including traffic count surveys (usually conducted at intersections and on road links), public transport passenger and NMT surveys (to estimate the demand on current transport systems and/or at public transport terminals, numbers of passengers accessing public transport facilities by foot, etc.) and origin - destination traffic and passenger surveys (to determine the origins and destinations of vehicles, and sometimes passengers).

Planned developments, land use changes and transportation infrastructure and services

The potential impact on traffic demand and transportation infrastructure of other planned developments in the vicinity of the proposed neighbourhood should be carefully considered. The transportation infrastructure needs of these developments will affect the proposed development. Information should also be obtained regarding potential changes in land use and any latent land use rights for development (rights that exist but have not been exercised).

It is important to know what transportation infrastructure is planned for the areas adjacent to and surrounding the proposed development. Liaise with the municipal, provincial and national transport authorities and transport agencies to understand planned new roads, public transport services and facilities and non-motorised transport facilities within the area. The proposed timing and phasing of these improvements should also be considered. They would normally go ahead whether the new neighbourhood is developed or not, but the new project may change the time lines and priorities assigned to these improvements.

Assign the future trip demand to the network

Based on all the information gathered, the future trip demand needs to be assigned to the various links and intersections making up the networks. This would allow for the demand flows on the links and at intersections to be estimated, and the required capacity of the links and intersections to be modelled. The trip assignment process is most commonly undertaken using simulation software that provides estimates of vehicle queues and delays at the intersection during the modelled period.

The resulting vehicular demand and capacity relationships across the network will determine the levels of service of the future network. Road-based vehicle levels of service in urban areas are most commonly influenced by the intersection layouts and controls, and the level of service is defined by the average delay experienced by a driver on an approach to the intersection. If the level of service is not initially satisfactory, the transport planner must introduce roadway and/or intersection improvements to alter the demand-supply relationship and hence establish acceptable levels of service. The analysis will also determine the type of intersection control that is required, i.e. stop, traffic circle or signals. In all cases, the provision for NMT at intersections is critical.

The roadway and intersection cross-sections and land requirements are determined as part of this process. The cross-sections must also cater for NMT and public transport vehicle infrastructure. If on-street parking is to be provided in certain areas, this must also be included in the cross-section. NMT and motorised vehicle conflicts should be avoided as far as possible when designing the intersections and NMT roadway crossing points.

Levels of service for NMT and public transport facilities are commonly determined by traveller densities in confined spaces such as stops and terminals, and by passenger flows in restricted spaces such as walkways and bridge crossings. Types of control at the NMT and motorised vehicle traffic conflict points must be carefully considered to ensure safety and convenience.

The arrangement of NMT and traffic at generators such as schools and hospitals must receive specific attention. At schools, the conflicts between vehicles and pedestrians and cyclists must be identified and carefully planned to ensure the maximum levels of safety. At other facilities such as hospitals and large retail facilities, individual vehicle access, egress, NMT and parking studies may be required.

Transportation simulation software

Transportation simulation software is used as a tool to assist transport planners in simulating the transport demand and supply relationship to determine suitable levels of service in the peak periods. Deciding on the most suitable software depends on the nature of the proposed development, the simulation needs of the transport system and the needs of the transport planner. Several software platforms are available to transport planners, and most reputable platforms are suitable for use. However, there are important issues that planners should consider when deciding whether to use a software platform, and if so, what type of software is most suitable. Transportation simulation can be done at essentially three levels:

- **Macro-level models:** These applications are for large area networks, typically regions or metropolitan areas. They are complex models that require substantial data sets for their development and are developed by metropolitan and provincial transport authorities. The transport planner may be dependent on such a model to obtain sub-area traffic and passenger demands.
- **Meso-level models:** These models are network-based and used to simulate smaller areas. They are commonly used for urban settlement trip simulation, and can simulate detailed intersection operations.
- **Micro-level models:** These models are most commonly used to simulate traffic intersections. They can be network-based or simulate isolated intersections. Transport planners are advised against using isolated intersection simulation models in urban areas with complex road networks.

I.3.3.2 Geometric design options

The purpose of geometric design is to shape the visible, physical components of streets and roads to enable the convenient, economical and safe movement of goods and people, regardless of their mode of transport, and in such a way that the negative impact on the environment and surrounding communities are minimised. The geometric design of streets and roads should support the objectives described in Section I.2.2 and contribute to the creation of neighbourhoods that accommodate all people, including those with disabilities.

The design of streets and roads influences, and is influenced by, the surrounding environment, and it is directly linked to the character of a neighbourhood. It is therefore important to also consult Section F, as the information about geometric design provided here is complemented by the information on neighbourhood layout and structure provided in Section F.

Geometric design involves the three-dimensional design of the road or street, and it is guided by various factors, including the characteristics of the natural environment (e.g. topography, vegetation, soil conditions) and built environment factors such as the nature of the environment alongside the street or road (e.g. houses, shops, street cafes, open space). Critically, not only should the needs of those making use of motor vehicles be considered, but also of those making use of non-motorised transport and of the sidewalks (pedestrians, cyclists, those with disabilities etc.). The key is to have a thorough understanding of the context within which the street or road will be embedded. Furthermore, it is important to adopt a holistic approach when making decisions regarding the geometric design of streets and roads. A range of disciplines may have a role to play, including engineers, planners, urban designers, landscape architects, architects, environmental scientists and hydrologists.

In essence, the geometric design of streets and roads involves the following three key aspects:

- Alignment (horizontal and vertical)
- Cross-sections
- Intersections

These aspects are briefly outlined below. Each aspect involves a range of interlinked components that are described further in Section I.4.1.

(i) Alignment

The horizontal and vertical alignment of streets and roads is closely linked to the layout and structuring of a neighbourhood as discussed in Section F, and the information provided in Section F.4.1.4 should specifically be referred to. More information is also provided in Section I.4.1.5.

Horizontal alignment

The horizontal alignment of a road or street is essentially the route that it follows if viewed on a map. From a geometric design perspective, it involves the design of the curves and straight sections (tangents), guided by certain calculations, to ensure the safety and comfort of the users of the street or road. The process to determine the horizontal alignment of a street or road is iterative in nature since various factors need to be considered, including the local topographical and other characteristics of the physical environment, as well as the layout and structuring options outlined in Section F.3.3 and design considerations discussed in Section F.4.

Vertical alignment

Streets and roads include sections that are sloping up or down, and sections that are commonly referred to as flat. This line that a street or road follows up and down a vertical plane is referred to as vertical alignment. As with horizontal alignment, factors that need to be considered include the topographical and other characteristics of the physical environment, as well as the layout and structuring options outlined in Section F.3.3 and design considerations discussed in Section F.4.

(ii) Cross-sections

The cross-section of a street or road has to accommodate moving and parked vehicles, non-motorised vehicles such as bicycles, pedestrians, wheelchairs, engineering infrastructure and utilities such as stormwater drainage, water, electricity, communications and sewer trenches (also see Section F.4.1.5). In some cases, it is also required to provide space for more than just movement-related activities such as formal and informal trading, socialising and recreational activities for children. Neighbourhood streets are often regarded as public open space and may have to fulfil a range of functions (see Section G.3.3.2).

The cross-section (also referred to as the road reserve) may comprise all or some of the following components:

- Traffic lanes for motorised vehicles (including dedicated lanes for high occupancy vehicles such as buses)
- Cycle lanes (they could be incorporated on the outside of traffic lanes, or they could be located on the verge, either as dedicated cycle lanes or combined with pedestrian walkways)
- Parking lanes (between the outside traffic lane and the verge, or embayed in the verge area)
- Verges (the area between the edge of the outside traffic or parking lanes and the road reserve boundary)
- Sidewalks (the part of the verge that accommodates pedestrian traffic, usually paved)
- Median islands (the area between the inner edges of the inside traffic lanes of a divided street or road)

The aspects to consider when designing cross sections are discussed in Section I.4.1.

(iii) Intersections

Roads and streets form a network, and it is inevitable that different sections of the network will meet (connect or cross) at certain points to create intersections. The movement of motorised and non-motorised transportation (including pedestrians) is restricted at intersections, and this could lead to congestion and accidents. It is therefore essential to ensure that intersections are able to deal effectively, efficiently and safely with all types of traffic. Intersections can take on various forms, including three-legged (commonly known as T-junctions), four-legged and multi-legged intersections. Different types of intersection control can be employed, for instance signilisation, multi-way stop or yield, mini roundabouts, traffic circles.

Pedestrian crossings are critical parts of intersections. They should make it possible for all people, regardless of age, to cross a street safely and conveniently, including people with physical, dexterity and sensory impairments, wheelchair users, people pushing prams, etc.

I.3.3.3 Road pavement options

When selecting a road pavement option, consider whether it meets the following requirements:

- a reasonably smooth riding surface
- adequate skid resistance (surface friction)
- favourable light-reflecting characteristics
- low noise pollution
- good waterproofing qualities
- protection of the natural soil subgrade

Decisions need to be made regarding the type of pavement as well as the material to be used. More information is provided below.

(i) Road pavement types

Road pavements can be classified as surfaced and unsurfaced. In turn, surfaced pavements can be categorised as flexible, semi-rigid and rigid, while gravel roads are regarded as having an unsurfaced pavement.[4] These types are briefly discussed below.

The classification does not only refer to the surface material, but encompasses all layers of the pavement structure (Figure I.2). The pavement structure refers to the combination of different layers (including the natural soil subgrade) that carries traffic loads. The layers have different functions, which determine the structural capacity and performance of the pavement. This performance is also affected by the climate, the traffic loading and the distress characteristics that occur in the pavement over time.

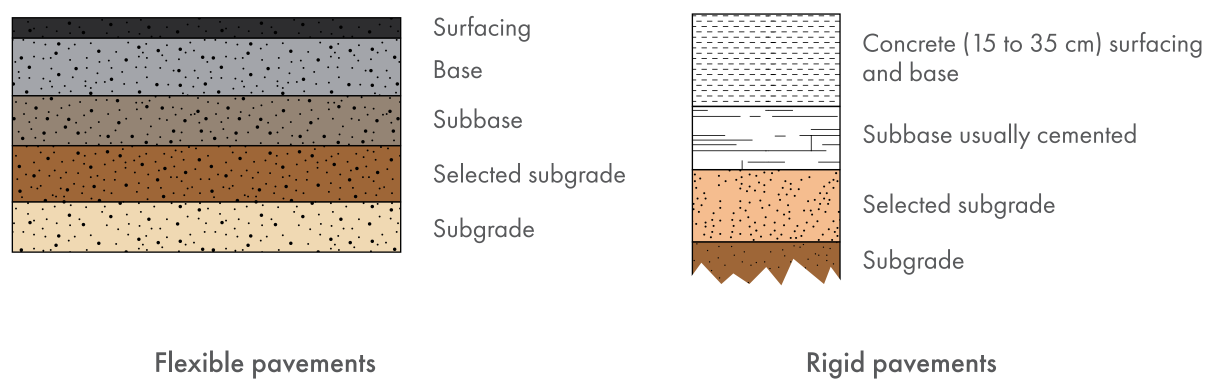


Figure I.2: Typical surfaced road pavement structures (adapted from SAPEM)[5]

Pavement structure

SAPEM describes the purpose of the various layers in the pavement as follows[6]:

- ***Surfacing:*** *This is a functional wearing course that provides waterproofing, skid resistance, noise-damping, durability against the elements, visibility and drainage. For surfaced roads, the upper layer is bound, consisting of spray seals.*
- ***Base:*** *This is a load spreading layer and is the most important structural component of the pavement. The layer must provide the required support for the surfacing and distribute the very high tyre pressures and wheel loads uniformly over the underlying layers and subgrade. The base comprises bound material e.g. asphalt, concrete or stabilised, or it can be unbound e.g. crushed stone or gravel base.*
- ***Subbase:*** *This layer provides support for the base as well as a platform upon which to construct a structural base layer of high integrity. It also protects the underlying selected subgrade layer by further spreading the load.*
- ***Selected subgrade:*** *These layers are primarily capping for the subgrade to provide a workable platform on which to construct the imported pavement layers. At the same time, these layers provide depth of cover over the subgrade to reduce the stresses in the subgrade to acceptable levels.*
- ***Subgrade:*** *This is the existing material upon which the pavement must be constructed. It can be modified with stabilisers to reduce plasticity, ripped and recompacted to achieve uniform support, or undercut and replaced, depending on its quality.*

Flexible pavements

Flexible pavements are usually designed in such a way that the material quality gradually, and smoothly, increases from the in-situ subgrade up to the structural layers and surfacing to form a well-balanced pavement structure. Alternatively, a granular base may be placed on a stronger, lightly cemented subbase to form an inverted pavement structure. Differentiation is also made between deep and shallow pavements:

- In shallow pavements, the strength of the pavement is concentrated in the uppermost layers.
- In deep pavements, the strength is distributed throughout the depth of the pavement.

Four types of flexible pavements are commonly used in South Africa, depending on the material used on the base layer. The four flexible pavement types include unbound granular, hot mix asphalt, bitumen stabilised and/or cemented base layer.

Semi-rigid pavements

Semi-rigid pavements consist of constructed concrete block paving or segmented concrete paving, in other words small individual shaped blocks laid on a sand bedding layer. Sand is placed in the joints between the blocks to fill the gaps and to enhance interlocking between the blocks. The concrete block system provides a durable wearing course, supported by subbase and selected layers, of which the thickness depends on the applied loading and subgrade strength. The concrete blocks carry much of the applied loading, but some load is distributed to the underlying layers.

Rigid pavements

Concrete roads, also referred to as rigid pavements, are particularly strong and have a very high modulus of elasticity. This results in great load spreading in the top layer and hence low stresses in the underlying substructure. Concrete pavements can be constructed on poor subgrades, and generally have fewer pavement layers than flexible pavements.

Gravel roads

Gravel or unpaved roads need a designed layer of imported material to carry specified loads in all weather conditions. The wearing course should also protect the subgrade below. The material requirements for these types of roads are less stringent in terms of strength, but have to be erosion-resistant. Typical challenges associated with gravel roads include dust, potholes, ruts, cracks, erosion and slipperiness. Gravel roads are not discussed in detail in this Guide, but more information is available in TRH20 - *Unsealed Roads: Design, Construction and Maintenance*[7] and *Towards Appropriate Standards for rural roads: Discussion document.*[8]

(ii) Road pavement materials

The selection of materials for pavement design is based on a combination of availability, economic factors and the documented track record of the material. These factors have to be evaluated during the design in order to select the materials best suited to the conditions. Standard material specifications are defined in guideline documents such as the following:

- TRH4: Structural Design of Flexible Pavements for Inter-urban and Rural Roads
- UTG3: Structural Design of Urban Roads
- TRH14: Guidelines for road construction materials
- The South African Pavement Engineering Manual (SAPEM)
- The SABITA manuals

Categorisation of pavement materials is done by considering issues such as the fundamental behaviour of the material as well as its strength characteristics. Available road material options are discussed below.

Granular materials

Unbound granular materials include graded crushed stone, natural and crushed gravels, sand and soils. Granular materials are typically used in the construction of the base, subbase and selected subgrade pavement layers. Certain types of gravel are also used for the wearing course of unpaved streets. In the TRH 14 classification system, the untreated or granular materials are classified as graded (engineered) crushed stone (G1 to G3), natural gravel (G4 to G6), gravel-soil (G7 to G10), macadam base layers and dump rock (DR). The selection of a type of gravel is informed by issues ranging from traffic load, availability of material, climate, to labour intensity of construction.

Cemented materials

Available local natural gravel materials are often found to be of inadequate quality to provide the required pavement structural strength. Cemented materials are formed when the materials with inadequate quality are treated or stabilised to improve their properties for use in selected subbase or base layers. The material can be treated using conventional stabilisers such as cement, lime, slagment, lime/fly-ash mixtures or various combinations of pozzolanic binders, depending on the properties of the natural materials.

Bitumen stabilised materials

Bitumen stabilised materials (BSMs) are pavement materials that are treated with either bitumen emulsion or foamed bitumen to improve their strength, as well as to reduce the moisture susceptibility of the material. The materials to be treated may be granular materials, previously cement-treated materials or reclaimed asphalt (RA) layers. The bitumen stabilised material may be used on new construction projects to treat the locally available material, and to enable the use of this material in the pavement base layer or on rehabilitation projects by treating the existing base material.

Hot mix asphalt materials

Hot mix asphalt (HMA) material may be used for the construction of surfacing and base pavement layers. HMA is composed of virgin aggregates or reclaimed asphalt (RA), filler and bituminous binders. The use of RA in HMA is considered to be economical and have environmental benefits, as it enables a reduction in consumption of non-renewable resources like petroleum products (fuel and bitumen) and aggregates, as well as in the use of landfill space for discarding asphalt removed from existing roads.

Spray seals and slurry seals or micro-surfacing

A spray seal comprises of a coat of bituminous binder sprayed onto the road surface, followed by a layer of aggregate. The layer is then rolled to ensure good adhesion between the aggregate and the binder film. The primary function of a spray seal or slurry seal layer is to provide a waterproof cover to the underlying pavement structure, provide a safe all-weather, dust-free riding surface with adequate skid resistance and to protect the underlying layer from the abrasive forces of traffic and the environment.

Primes, tack coats and pre-coating fluids

Primes, tack coats and stone pre-coating fluids are essential materials in the construction and maintenance of roads. A prime consists of a bituminous binder and is used as a preliminary treatment on a granular layer prior to application of an asphalt layer, to promote adhesion between the two layers. A tack coat is also a bituminous product that is applied either on top of a primed granular base or between layers of asphalt to promote adhesion and enhance adhesion along transverse and longitudinal joints in asphalt layers. Pre-coating fluid is low viscosity bitumen and is used to pre-coat surfacing aggregates to improve the adhesion of the aggregate to the bituminous binder, as well as to reduce the possibility of early chip loss and stripping.

Portland cement concrete

The use of concrete as a surface layer is not very common in South Africa, but it offers significant compression and flexural strength, resulting in a very durable structural surface layer that needs very little maintenance during its design life. Concrete is completely resistant to petrol and diesel spillages, which makes this surface ideal for bus depots, fuelling stations, parking lots and overnight rest areas where oil and fuel leaks/spillages can be problematic. The most popular types of rigid pavements used in South Africa include the following:

- Conventional concrete pavements: Plain jointed concrete pavement with no steel (JCP); Dowels and tie bars (steel rods placed at joints), transversely and longitudinally; and Continuously reinforced concrete pavements (CRCP)
- Precast concrete slab pavements

- Roller-compacted pavements (RCC)
- Ultra-thin concrete pavements (UTCP): For low-volume roads (typical less than 2 000 vehicles per day) and for high-volume roads
- Pervious or porous concrete pavement (PCP)

Paving blocks

Concrete block paving, also referred to as segmented concrete paving, comprises singular shaped blocks interlocking with each other to create a durable wearing course, supported by subbase and selected layers. Precast paving blocks have been successfully used in South Africa for non-trafficked areas, such as walkways, as well as heavily trafficked streets.

Various proprietary products

Proprietary construction products or systems are manufactured and distributed under exclusive rights, but these products are not usually covered by the national standard. However, they may be standard products in the sense that they meet the requirements of local or foreign standards, or they may be non-standard or innovative, in that there are currently no applicable standards.

I.4 Design considerations

The layout of the movement network contributes significantly to functionality of a neighbourhood and to its attractiveness to residents. Streets also form conduits for essential services such as water supply, sewerage, power and cabling. It is therefore essential that all relevant planners and designers work closely together, especially the transport planner, the town planner, the stormwater engineer, the geometric designer and the road pavement design engineer. It is essential that the information on stormwater management provided in Section L be used to inform decisions made regarding transportation infrastructure design.

Two key aspects related to transportation infrastructure and services are discussed below, namely geometric design and road pavement design.

I.4.1 Geometric design

Geometric design aims to optimise efficiency and safety while minimising cost and environmental damage. As mentioned in Section I.3.3.2, geometric design essentially deals with horizontal and vertical alignment and the design of cross-sections and intersections. The information provided below focuses on the key principles that should be considered with respect to each of these three aspects. Furthermore, these aspects are informed by a number of factors (or design parameters), in particular the design vehicle, speed parameters, traffic volumes, densities and composition, and sight distances, as outlined below. These parameters enable a consistent approach to geometric design and align the design of the street with the expectations of street users. If the approach to geometric design is consistent, the user will not be caught off guard by an unexpected feature of the street, resulting in more predictable user behaviour and, ultimately, improved safety.

Geometric design is strongly influenced by engineering principles as well as contextual factors, and requires specialist knowledge and experience. For more detailed information, it is recommended that suitably qualified professionals refer to the *Geometric Design of Roads Handbook*[9] written by Keith M. Wolhuter.

I.4.1.1 The design vehicle

Road and street networks need to be designed to accommodate a range of motorised and non-motorised vehicles (including pedestrians). The different physical dimensions and operational characteristics of these vehicles have to be taken into consideration when designing a street. However, it would not be possible to use all the features of all the possible vehicles that may make use of all streets, and the design vehicle represents a combination of the critical features of all the vehicles of a particular type or class. A number of different types of design vehicles can be used to guide the design of a particular street, for instance to influence street dimensions such as the width of vehicle lanes and pedestrian sidewalks, curves and the radii of bends at intersections.

Design vehicles can broadly be grouped into two categories, namely motorised vehicles and non-motorised vehicles.

(i) Motorised vehicles

The most common types of motorised vehicles that use neighbourhood streets are passenger cars, buses and trucks. These include minibus taxis, recreational utility vehicles and light delivery trucks (vans and bakkies). Different design vehicles are usually defined to represent different types of vehicles (e.g. passenger cars and bigger vehicles such as buses). The critical features that are taken into consideration when defining the design vehicle include dimensions (e.g. length, width, height, ground clearance, wheel base, front overhang and rear overhang), operational factors (e.g. power-to-weight ratio, braking capability and deceleration rates, minimum turning circle radius and swept path).

The features of the design vehicles are used to inform various aspects of geometric design. For instance, the power-to-weight ratio, particularly of trucks, is used to derive the truck speed on gradients. Another example relates to turning circles, which indicates the manoeuvrability of a vehicle. A smaller turning radius will improve manoeuvrability, while a large radius may make it difficult for a large vehicle to negotiate a sharp turn. The turning radius is used when designing intersections and on-street parking.

The operational characteristics of motorised vehicles are not only influenced by the vehicle, but also by the driver. There are many driver characteristics that could or should (depending on availability of data) be considered when doing the geometric design of roads, including the driver's age, decision-making methods, information processing and psychological status.

Two motorised vehicles are recommended for use in the design of neighbourhood roads. The passenger car should be used for speed-related standards and the bus for standards relating to manoeuvrability, typically at intersections. The bus also dictates the maximum permissible gradient.

(ii) Non-motorised vehicles

The most common forms of non-motorised transport (NMT) are walking and cycling. The pedestrian and cyclist have certain physical design dimensions and operational characteristics that have to be considered in the design of streets. Other forms of NMT include people pushing prams or trolleys, people using wheelchairs, push carts and animal-drawn vehicles. More information regarding the various types of NMT users is available in the *NMT Facility Guidelines*[10].

Information related to NMT used to define design vehicles involves, for instance, travelling speeds. Walking speed varies depending on a number of factors such as the number of pedestrians in a given space, the surface covering, the reason for walking (e.g. to and from work or public transport, leisure, window shopping), the age of the pedestrian and whether the person has a disability or not. The walking speed used to guide geometric design decisions should be adjusted according to the expected conditions. In general, a lower walking average speed should be applied when designing streets and pathways in the vicinity of old-age homes, hospitals and schools. Walking speed is useful for calculations related to, for instance, the design of pedestrian crossings.

In addition to travelling speed, dimensions are also used to inform geometric design decisions. For instance, the space needed per person at a pedestrian crossing would be less than the space needed by pedestrians on the move. Also, cyclists, people using wheelchairs and pedestrians with luggage will require more space than regular pedestrians. This information will inform design decisions related to, for instance, the width of walkways and cycle paths.

Other forms of NMT may also have to be considered. For instance, in certain neighbourhoods it may be necessary to design streets to accommodate animal-drawn carts.

I.4.1.2 Speed parameters

There is an interrelated relationship between the design of a street and the speed at which motorists will travel along that particular street. On the one hand, the design of a street is informed by the anticipated speed at which it would be used. On the other hand, the speed at which the street will eventually be used will, to a large extent, depend on the geometric design features of the street. To assist with geometric design decisions, a design speed and an operating speed are used.

The design speed can be regarded as the maximum safe speed that can be maintained on a street when traffic conditions are so favourable that the speed selected by a driver is determined by the characteristics of the street. In reality, this speed would of course also be influenced by other factors such as the driver's proficiency and ability to react (reaction time), the condition of the vehicle (particularly its brakes and tyres), the weather conditions and the time of day (since it may affect visibility).

The design speed is a speed selected for the purposes of designing those features of a street that would affect the safe operation of vehicles, for instance horizontal and vertical curvature, sight distance and superelevation. Design speed is linked to the functional classification of the street, the context (e.g. presence of pedestrians, adjacent land use and topography), as well as the anticipated operating speed.

The operating speed relates to the actual speed at which vehicles travel along a particular street. Often this is higher than the design speed. The geometric design of a street could influence the speed at which vehicles are comfortably able to travel. In some cases, design interventions could be implemented to reduce operating speeds, for instance on streets in the vicinity of schools, old age homes, public transport stops, and areas where there is high levels of pedestrian activity.

I.4.1.3 Traffic volumes, densities and composition

The nature of the traffic that a particular street is expected to carry in future is measured as the estimated number of vehicles per hour (traffic volume) and vehicles per kilometre (vehicle density). This information needs to be provided for different types of motorised and non-motorised transport (composition). It provides an indication of the traffic conditions that a street should be designed for. It could, for instance, influence the design of the cross-section of a street, particularly the number of lanes required in each direction, and it could also affect the location and design of intersections.

I.4.1.4 Sight distance

Sight distance refers to the distance between a road user's eyes and a specific object or road feature that has to be seen by the user. Different sight distances are applicable depending on the aspect of the street that has to be designed. The intention is to allow a user of a motorised or non-motorised vehicle to observe a potential hazard in time to react effectively and safely. Different types of sight distances are used in calculations related to various aspects of geometric design.

One type of sight distance is referred to as stopping sight distance. This is the distance that is required for a driver to safely bring a vehicle to a standstill after observing a potential hazard. Stopping distance includes the distance covered during the time that the driver takes to react and the distance that it takes for the vehicle to come to a complete stop. Various factors influence stopping sight distance, including vehicle speed, driver reaction time, road conditions and skid resistance.

Other types of sight distance include barrier sight distance, decision sight distance, passing sight distance and intersection sight distance. Intersection sight distance also involves sight distance specifically applicable to pedestrians. This is used to design street crossings that allow pedestrians to safely cross an intersection.

I.4.1.5 Horizontal alignment

Horizontal alignment (as described in Section I.3.3.2) affects, and is affected by, the factors mentioned in Sections I.4.1.1 to I.4.1.4. In addition, horizontal alignment is also influenced by vertical alignment, and vice versa. For instance, the street layout and horizontal alignment of a neighbourhood may be determined to some degree by the vertical characteristics of the site, especially if the terrain is hilly.

General principles to be observed in the determination of the horizontal alignment of a road or street are the following:

- Short lengths of tangent (straight) should be used between reverse curves so vehicles traversing a curve in one direction do not have to immediately traverse one in the reverse direction.
- Broken back curves (where two curves in the same direction are separated by a short tangent) should preferably not be used, as drivers generally do not expect this.
- Large- and small-radius curves should not be mixed. Successive curves to the left and the right should generally have similar radii.
- For small-deflection angles, curves should be sufficiently long to avoid the impression of a kink.
- Alignment should be sensitive to the topography to minimise the need for cuts and fills and the restriction that these place on access to plots from the street. Streets at right angles to the contours can create problems in terms of construction, maintenance, drainage, scour (in the case of gravelled surfaces) and also constitute a traffic hazard. During heavy rainstorms, water flowing down a steep street can flow across the intersecting street.

Curves in the road are often accompanied by superelevation, which is the upward slope of the road from its inner to outer edges. This helps to counteract the centrifugal force exhorted on a vehicle negotiating a curve. In urban areas, superelevation is not always required or possible. Care should be taken not to introduce superelevation, which would make it difficult to access properties alongside the street due to the one edge of the street being elevated above natural ground level.

I.4.1.6 Vertical alignment

Similar to horizontal alignment, vertical alignment (as described in Section I.3.3.2) affects, and is affected by, the factors mentioned in Sections I.4.1.1 to I.4.1.4. As previously mentioned, vertical alignment is also influenced by horizontal alignment, and vice versa.

Vertical alignment is the combination of parabolic vertical curves and straight sections joining them. Straight sections are referred to as grades, and the value of their slope (steepness) is the gradient, usually expressed in percentage form, e.g. a 5% grade means a climb through 5 m over a horizontal distance of 100 m.

A smooth grade line with gradual changes appropriate to the class of road and the character of the topography is preferable to an alignment with numerous short lengths of grade and vertical curves. The "roller coaster" or "hidden dip" type of profile should be avoided. For aesthetic reasons, a broken back alignment is not desirable in sags where a full view of the profile is possible. On crests, the broken back curve adversely affects passing opportunity. The minimum rate of curvature is usually determined by sight distance, the level of ease with which it can be traversed, as well as aesthetic considerations.

On neighbourhood streets, gradient may have a significant effect on the cost of the development. Where possible, road alignment should be designed to minimise the extent and cost of earthworks and to avoid problems with access and house design. It therefore has to be accepted that short sections of steep gradients may be necessary in some township developments.

The following should be taken into consideration:

- According to the *National Technical Requirement 1: Pedestrian Crossings* (NTR 1)[11], gradients along the path of pedestrian and NMT travel shall not be steeper than a ratio of 1:12 (8.33%) and is preferred to be a ratio of at least 1:15 (6.66%).
- Gradients should be selected in consultation with the stormwater design engineer, as steep gradients on short access loops and cul-de-sacs could result in properties being flooded and surface runoff washing across intersecting streets.
- Gravel surfaces are subject to scour at water flow speeds of the order of 0.6 to 1.0 m/s. Under conditions of overland flow, this speed is achieved at slopes of the order of 7% to 8%. The slope in question is the resultant of the vectors of longitudinal slope and crossfall.

I.4.1.7 Cross-section design

As discussed in **Section F.4.1.5**, the cross-section of a street provides space for moving and parked vehicles, non-motorised vehicles such as bicycles, pedestrians, engineering infrastructure and utilities such as stormwater drainage, water, electricity, communications and sewer trenches. In addition, it may also have to accommodate activities other than those related to movement. Residential streets, for example, offer a neutral terrain on which neighbours can meet informally. They can also serve as playgrounds for children, especially in developments where plot sizes are too small for this purpose. Refer to **Section G.3.3.2** for a discussion on how streets are used as public open spaces in a neighbourhood.

Designing the cross-section of a street involves, firstly, selecting the relevant components to be included, and secondly determining their dimensions based on an understanding of the context and factors such as future traffic volumes, densities and composition. The cross-section may comprise all or some of the components summarised below.

Lanes for motorised vehicles

The number and width of traffic lanes provided would depend on a number of factors, including the location, purpose and classification of the street or road. The selection of lane width has traditionally been based on traffic volume and motorised vehicle type and speed. However, issues such as the availability of land, the impact of adjacent land uses and the specific needs of local communities also have an impact on the width of lanes. A distinction is often made between basic lanes and auxiliary lanes. The former are usually extended over long distances of the road, while the latter are only added to the cross-section to serve a short-term need.

Camber and crossfall

Camber implies two slopes away from a central high point, as in a two-lane two-way road, where the cross-section slopes down from the centre line to the shoulders. Crossfall is a single slope from shoulder to shoulder. The slope, whether camber or crossfall, is provided to facilitate drainage of the road surface.

In the case of very narrow reserves, such as in the case of lanes or alleys where spatial restrictions may preclude the provision of drainage outside the width of the travelled way, a negative or reverse camber, i.e. sloping towards a central low point, could be considered. In this case, the centre line of the street is the low point to create a flat V configuration. The entire surfaced width then serves as a drainage area.

In exceptional cases, local residential streets may have only one lane, with provision for passing made at intervals. Bus Rapid Transit (BRT) systems in South Africa make use of exclusive bus lanes. BRT buses operate for (at least) a significant part of their journey within a fully dedicate right of way, in order to avoid traffic congestion.

Verges

The verge is defined as the area between the roadway edge and the road reserve boundary. The verge width is the sum of the various elements it is required to contain. As discussed in Section F.4.1.5, there is a range of functions and activities that have to be accommodated. Some municipalities have developed their own specifications and guidelines and information is also provided in *TRH26: South African Classification and Access Management Manual* and in *TRH 27: South African Manual for permitting services in the Road Reserve*. The different elements that might be included in the verge include sidewalks, cycle lanes, parking and loading space, streetlights and street furniture, street trees and landscaping, public transport bays and services reticulation such as trenches for sewers, water pipes, stormwater pipes, electricity cables and telecommunication cables as well as stormwater channels (see Section F.4.1.5).

Cycle lanes

If at all possible, cycle lanes should be located in the verge area as the speed differential between bicycles and pedestrians is likely to be less than that between bicycles and motorised vehicles. Where this is not possible, a cycle lane can be added outside those intended for motorised vehicles. Such lanes should be of the order of 1.5 m wide and clearly demarcated as cycle lanes. If these lanes are wider than 2 m, passenger cars are likely to use them, possibly even for overtaking on the left, which is a manoeuvre to be actively discouraged.

Sidewalks

Ideally, all neighbourhood streets should have sidewalks on both sides. A sidewalk comprises the entire width between the kerb and the road reserve boundary. According to *NTR 1*, sidewalks should be at least 1.2 m wide when used for pedestrians only. This space should be clear and unobstructed. In shared space configurations, where cyclists and other NMT users are to be accommodated on the sidewalk, the clear and unobstructed space should be at least 3 m wide.

NTR 1 provides details on the design and measurements for drop kerb ramps or kerb cut options (also called a dropped intersection) to get pedestrians to the road level before crossing the road. The decision as to whether a dropped kerb or a dropped intersection is an option will depend on the width of the sidewalk. The total space required for the installation of the ramped surfaces has to be accommodated in the width of the sidewalk.

Shelter and a pleasant walking environment is an important part of promoting NMT and can be served through the planting of trees in the space for signage and utilities, which is located within the first 0.5 m from the kerb edge. All street furniture is to be located in the designated service areas, to prevent cluttered pedestrian access areas.

Median islands

The median island is the total area between the inner edges of the inside traffic lanes of a divided road, and includes the inner shoulders and central island. For higher-order roads, the purpose of the median is to separate opposing streams of traffic and hence reduce the possibility of vehicles crossing into the path of opposing traffic. Within the neighbourhood context, the number of lanes determines the road-crossing distance for pedestrians and will determine when a median will be required to provide an area of refuge for pedestrian safety.

Street lighting

One of the purposes of street lighting is to enable vehicles and people to move safely and comfortably in public open space. The design of street lighting luminaries is addressed in the CIE 140 standard for road lighting calculation.[12] The standard deals with the calculation of luminance and illuminance, and introduces conventions for the location of calculation grid points and observer positions. It also covers the computer programs that can be used for calculations. Other important standards that are applicable for street lighting design are *SANS 10098 – 1*[13] and *SANS 10098 – 2*[14] which are substantially applied by municipalities and utilities in the design of their street lights.

Street lighting is categorised as follows: Group A covers the lighting of important routes; Group B deals with the lighting of residential streets and Group C refers to special lighting requirements. There are different methods of design that can be used for each of the different groups. These methods are described in *SANS 10098 – 1*. The first method involves certified luminance performance tables, while the second method makes provision for the use of computer calculations.

New street lighting technologies are constantly being developed, and energy-efficient technologies are becoming increasingly popular. An overview of lighting technologies is presented in the *Efficient public lighting guide.*[15] Maintenance is an important aspect to consider when designing street lighting. Information regarding maintenance is provided in *ARP 035:2014.*[16]

I.4.1.8 Intersections

Intersections are required to accommodate the movement of both motorised and non-motorised transport. For both groupings intersections have a lower capacity than the links on either side of them. The efficiency of the intersections therefore has a significant impact on the efficiency of the network as a whole when measured according to factors such as energy consumption, time, safety and convenience.

A large proportion of accidents occurring on the road network takes place at intersections. For reasons both of efficiency and safety it is therefore necessary to pay careful attention to the design of intersections. Aspects of design that have to be considered include the location and spacing of intersections, and the form of the intersection linked to the type of intersection control. These aspects are briefly outlined below.

Location and spacing of intersections

The location and spacing of successive intersections is essentially a function of the layout planning of the area being served (see **Section F**). Various factors related to neighbourhood layout and structure (as discussed in **Section F.4**) need to be taken into consideration, including street hierarchy, street block length, the nature of the streets and the needs of pedestrians and other NMT users.

Intersection sight distance is critical for all users of the intersection to be able to enter and exit the intersection safely. Users should have unobstructed views of the entire intersection and any potentially conflicting vehicles before entering. The location of an intersection on a horizontal curve can create sight problems for the drivers on both legs of the intersecting road and should be avoided where possible. The risk involved in sharp braking during an emergency should also be borne in mind when locating an intersection on a curve.

It is suggested, as a safety measure, that intersections should not be located on relatively steep grades. Drivers have difficulty in judging the additional distance required for stopping on downgrades, and buses and freight vehicles have difficulty in stopping and pulling away on steep slopes.

One of the consequences of a collision between two vehicles at an intersection is that either or both may leave the road. It is therefore advisable to avoid locating an intersection other than at approximately ground level. Lateral obstructions of sight distance should also be considered when the location of an intersection is being determined.

The location of an intersection may have to be modified as a result of an excessive angle of skew between the intersecting roads, i.e. the change of direction to be negotiated by a vehicle turning left off the through-road. Preferably, roads should meet at, or nearly at, right angles.

On higher-order roads, the ideal distance between successive intersections should be such that traffic flows along them should be at so-called "green wave conditions", which means that traffic signals change to their green phase as approaching groups of vehicles reach them. Minimum distances between intersections are primarily concerned with the interaction between these intersections. A driver cannot reasonably be expected to utilise the decision sight distance to an intersection effectively if an intervening intersection requires his or her attention.

On residential streets, the spacing of intersections is at shorter intervals and primarily determined by the layout of the streets providing access to the various plots. The spacing of intersections should be such that they are not so close that waiting traffic at one intersection could generate a queue extending beyond the next upstream intersection. Very closely spaced intersections would also result in a disproportionate percentage of space being dedicated to the road network.

The form of intersection and type of control

When decisions have to be made about the form of an intersection and the type of traffic control measures to employ, each intersection should be considered on its own merits. Volumes of vehicular traffic being served by the intersection are but one aspect to consider. Safety is enhanced by inter alia reducing the number of conflict points at which accidents can occur. The number of conflict points increases significantly with the number of legs added to the intersection. In addition to the decrease in safety with an increasing number of approaches to an intersection, there is also a decline in operational efficiency, i.e. an increase in delay.

Four- and three-legged intersections are most common. Multi-leg intersections, i.e. intersections with more than four legs, should be avoided as far as possible. Other forms of intersections and types of control that can be employed include mini-roundabouts, traffic circles and gyratories.

The primary difference between these three forms of control is the diameter of the central island. The gyratory can have a central island with a diameter of 50 m or more, whereas the traffic circle would typically have a central island with a diameter of the order of 10 m and the mini-roundabout a central island that could range from a painted dot to about 4 m diameter. These three forms may have different interpretations depending on the local circumstances. They have advantages as well as disadvantages, and each location should be carefully assessed before deciding on one of these options.

Mini-roundabouts are often challenging for pedestrians and cyclists to negotiate. The need for vehicles to stop at the intersection is reduced, and traffic flow may not be easy to anticipate. Crossing opportunities for cyclists and pedestrians are reduced and the task of judging acceptable gaps could be difficult. The circulatory flow and reduced carriageway width offer less protected space for cyclists. In addition, the distinction between behaviour at a traffic circle and that required at a mini-roundabout is not clear to many drivers.

Signalised intersections usually apply to higher-order roads and are an expensive form of control. The aim of a signalised intersection is not, in the first instance, to reduce speed/calm traffic. By imposing a delay on the through flow, the intersecting flow will be allowed to either cross or join it.

A multi-way stop or yield intersection implies that every approach to the intersection is subject to stop or yield control. Some municipalities in South Africa have also instituted a variation on this form of control by applying stop control not to all but to the majority of approach legs, e.g. two out of three or three out of four. The operation of intersections subject to this form of control grants priority to vehicles based on the principle of “first come, first served”. This form of control is appropriate to the situation where no clear distinction can be drawn between the intersecting roads in terms of relative importance and where traffic flows on each are more or less equal. It is often regarded as an interim measure prior to the installation of traffic signals.

Priority control implies that one of the intersecting roads always takes precedence over the other with control taking the form of either ‘stop’ or ‘yield’ control. This form of control applies to the situation where it is clear which is the more important of the two intersecting roads. Priority control can also be alternated between successive intersections, for example in a residential area where the layout is more or less a grid pattern and the intersecting streets are of equal importance. In this case, the switching of priority would partially serve as a traffic-calming measure. In general, this is the most commonly used form of intersection traffic control.

I.4.2 Road pavement design

This section focuses on the structural design of urban road pavements, including neighbourhood streets, sidewalks and cycle lanes. The aim of structural design is to produce a structurally balanced pavement structure which, at minimum present worth of cost (PWOC) (see Section I.4.2.8), will carry the traffic for the structural design period in the prevailing environment, at an acceptable level of service (LoS) (see Section I.4.2.1) without major structural distress.

The stepwise pavement design process is detailed in the flowchart in Figure I.3. The various steps are used to structure the road pavement design guidance provided in the remainder of this section (I.4.2).

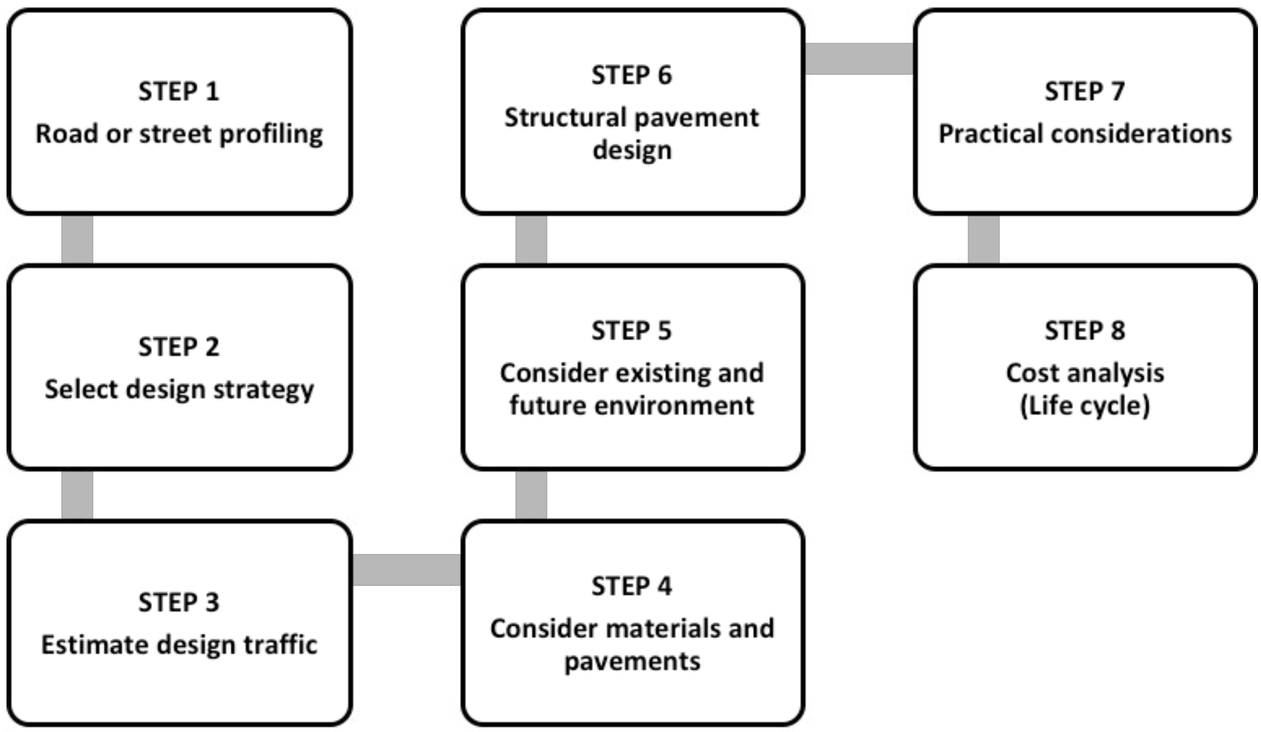


Figure I.3: Conceptual road pavement design flowchart

I.4.2.1 Street profiling

Compiling a street 'profile' is a critical aspect of the pavement design process. A number of characteristics define the profile of a street, including the street category, the description and function of the street, the level of service of the street, vehicle and pedestrian traffic, pavement design bearing capacity and whether the street is paved or unpaved.

The six-tiered urban functional road or street classification of TRH26 is discussed in **Section I.2.3.1**. For the purpose of pavement structural design, it is important to note that the TRH26 manual differentiates between roads in rural areas and roads in urban areas. In the manual an urban area is defined as an area that has been subdivided into plots, whether formal or informal. It includes formally declared townships as well as informal settlements. This Guide focuses on neighbourhood streets, which are defined in TRH26 as urban.

According to *TRH4: Structural Design of Flexible Pavements for Inter-urban and Rural Roads* and *TRH22: Pavement Management Systems*, roads can also be divided into four broad risk-based categories based on design reliability. This is done for pavement management purposes (see Table I.2).

Table I.2: Generic risk-based structural road categorisation (modified from TRH4, 1994 and TRH22, 1994)		
Road structural category*	Approximate design reliability (%)	Description
A	95	Inter-urban freeways, major inter-urban rural roads
B	90	Inter-urban collectors, major rural roads, major industrial
C	80	Lightly trafficked rural roads, strategic roads
D, E**	50	Special pavements, access roads, walkways, cycle lanes, walkways, sidewalks, NMT, etc.

* Diminishing approximate design reliability, "Category A" highest, i.e. lowest risk for failure. Risk of failure (%) = (100 minus Design Reliability, in %).

** E added for walkways, cycle lanes and NMT modes such as carts, etc.

For the purpose of pavement structural design, this Guide combines the classifications of TRH26 and TRH4 to identify five different street classes/categories, namely U2-B, U3-B, U4-C, U5-D and U6-E. These categories range from arterial streets with high volumes of traffic (low risk of failure), to lightly trafficked residential streets and walkways (higher risk of failure). Although this Guide is focused on the design of neighbourhood streets, information on the structural design of certain higher-class roads (U2-B and U3-B) is also included.

The detailed pavement and traffic engineering definitions of the five combined road/street classes and categories for structural pavement design purposes are summarised in Table I.3.

Table I.3: Definition of the combined road classes and categories for structural pavement design purposes				
Combined Road Class Category	U2-B	U3-B	U4-C	U5-D, U6-E
Description	Major arterial	Minor arterial	Collector street	Local Street Walkway*
Basic function	Mobility		Access/Activity	
Level of Service (LoS): Scale: 5 to 1	High: 4	High to Moderate: 4 to 3	Moderate: 3	Moderate to Low: 3 to 1
Approximate design reliability (%)	90	90	80	50
Length of road exceeding terminal condition at the end of design life (%)	10	10	20	50
Equivalent 80 kN single axle loading (million E80/lane), including construction traffic	0.3 to 10 depending on design strategy	0.3 to 10 depending on design strategy	< 3 depending on design strategy	< 1 depending on design strategy
Typical Traffic Loading Class (TLC) in terms of Equivalent Standard (ES) 80 kN axle loads	ES1 – ES10	ES1 – ES10	ES0.03 – ES3	ES0.003 – ES1
Daily Traffic: Equivalent vehicle units (EVU) (1.25 veh=1 EVU)	600 to 10 000	600 to 10 000	< 600	< 500

Table I.3: Definition of the combined road classes and categories for structural pavement design purposes

Combined Road Class Category		U2-B	U3-B	U4-C	U5-D, U6-E
Description		Major arterial	Minor arterial	Collector street	Local Street Walkway*
Riding quality: International Roughness Index (IRI) (m/km)	Constructed	2.9 to 1.6	2.9 to 1.6	3.5 to 2.4	4.2 to 2.4
	Terminal	4.2	4.2	4.5	5.1
Flexible pavements rut level (mm)	Warning	10	10	10	10
	Terminal	20	20	20	20
Area of shattered concrete or rigid pavements (%)**					
CRCP and UTRCP	Warning	0.3	0.3	0.48	0.5
	Terminal	0.7	0.7	0.8	1.0
JCP and DJCP	Warning	3	3	4	5
	Terminal	6	6	8	10
Typical standard for surfacing		Paved/ unpaved	Paved/ unpaved	Unpaved, or paved for reasons other than traffic (e.g. drainage)	Unpaved, or paved for reasons other than traffic (e.g. drainage)
Pedestrian traffic		Low	Low	High	High

* Include non-motorised transport (NMT)

** CRCP: Continuous Reinforced Concrete Pavement, UTRCP: Ultra-Thin Reinforced Concrete Pavement, JCP: Jointed Concrete Pavement, DJCP: Doweled Jointed Concrete Pavement

Another factor to consider is the level of service (LoS). The LoS that a user expects from a street is related to the function of the street, whether it is paved or unpaved, and partly to the volume of traffic carried. For example, the user will expect a better riding quality on a dual-carriageway arterial road than on a minor residential street. Irrespective of this, the user will generally expect the highest possible standard. Different streets within a neighbourhood function at different LoS. The LoS values can be determined by the functional use of the street and the drainage provision on a five-point scale, with 5 as highest LoS. In Table I.4 the description of each type of street and its drainage is given, with the associated LoS values. In the matrix the combined LoS value is given. The final LoS value is determined mostly by the LoS of the water drainage.

Table I.4: Levels of Service (LoS) of streets or drainage and combined facilities

Combined Road Class Category	Street LoS*	Drainage LoS:	4 & 5	3	2	1
		Description	Pipe system, kerbs, gutter and surfaced (paved) street	Lined channel on shoulder or on street	Unlined channel on shoulder or on street	Unsurfaced street with provision of drainage with sheet flow
U2-B, U3-B	5	District and/or local distributors (bus routes) with a designed structure and surfacing	5	4	3	
	3	Gravel		3	2	
U4-C	5	Residential access collectors with a designed light structure and surfacing	5	4	3	2
	3	Gravel		3	2	1
	1	In situ		3	2	1
U5-D, U6-E	5	Access and basic access streets with surfacing on light structure	5	4	3	2
	3	Gravel		3	2	1
	1	In situ		3	2	1

* LoS on a five-point scale, with 5 as the highest quality.

Table I.5: Categorisation of urban street and route standards

Paved collector/distributor streets (bus routes, may include Bus Rapid Transit (BRT))	Unpaved collector/distributor streets (bus routes)	Access streets (> 75 vehicles per day)		Basic access streets (< 75 vehicles per day; < 5 heavy vehicles per day)			
		Paved access streets	Unpaved access streets	Paved basic access streets	Unpaved basic access streets		
					Gravel basic access streets	Earth basic access streets	Tertiary ways

The main categories as highlighted in Table I.5 are discussed below.

I.4.2.1.1 Arterial streets

Arterial streets are the major routes providing mobility between and within residential, recreational, commercial and industrial areas. The traffic volumes on these streets will be high and the streets will generally carry significant numbers of buses and other heavy vehicles such as construction vehicles. The heavy vehicle traffic carried by paved arterial streets will generally justify their being built to a traditional paved standard for bearing capacity, if funds are available.

Although unpaved arterial roads and streets exist in some areas, the cost of maintaining such infrastructure can be excessive. If not maintained frequently, such roads may not retain a riding quality of an acceptable level and it may result in safety hazards and dust pollution. The user costs, in comparison with a paved street, are extremely high. All attempts should be made to provide arterials carrying bus and heavy goods vehicles of a suitable, relatively low-risk, paved standard, whilst arterials carrying mostly light goods vehicles can afford slightly higher-risk pavements. Although undesirable, financial constraints may prevent an authority from being able to pave all arterial streets in a road network. The optimum use of available materials is thus necessary to reduce the undesirable effects as far as possible.

I.4.2.1.2 Access streets

Access streets include all residential streets below the level of urban bus routes. Their primary function is access to residential erven and they will thus carry few heavy vehicles. Depending on the level of development and car ownership in the area, traffic may be so light that the primary structural design objectives may relate more to minimising damage from water erosion than to supporting traffic loading. Access streets may be further divided into access streets with traffic levels of more than 75 vehicles per day (vpd) and those with less than 75 vehicles per day, of which less than approximately 5 are heavy vehicles. Access streets carrying more than 75 vehicles per day require a more robust structural design than those carrying lighter traffic volumes (basic access streets).

It may be economically justifiable to pave access streets with traffic levels of more than 75 vehicles per day. The aspirations of residents and street users may also influence this decision.

I.4.2.1.3 Basic access streets

Basic access streets are defined as access streets in the early stages of development, and are designed and constructed subject to constraints imposed by the administrative authority owing to limited budgets or other circumstances. The objective is to maximise the longer-term performance of such streets within these constraints.

Access streets with relatively light traffic can justifiably be left unpaved. If the street is to have an unsealed pavement it is essential that the best quality material available locally is used (blending and/or processing should be considered where necessary to improve the materials), and some method of dust palliation could be considered.

Although unpaved basic access streets are undesirable from the point of view of dust generation, the creation of mud when wet, the need for constant maintenance, and financial constraints may preclude the use of higher-quality streets for the very low traffic loading typical of these streets. The optimum use of available materials is thus necessary to reduce the undesirable effects as far as possible.

Earth basic access streets are considered a viable option only if the in-situ material is of a quality that will support vehicles even in a soaked condition. One of the major problems with earth streets is that they initially form tracks, and, if bladed, a street that is lower than the surrounding terrain results, with significant drainage and erosion problems.

I.4.2.1.4 Tertiary ways

Unpaved basic access streets may evolve from informal access routes, which are referred to as tertiary ways. In developing areas, an infrastructure of narrow ways that carry no or few vehicles exists. These non-trafficked tertiary ways are mostly informal and un-serviced, but in older developing areas they are formalised (upgraded) by the provision of surfacings, drainage or even services like water and electricity.

In an informal residential development no layout planning for tertiary ways is done. The existence of these ways is dictated by pedestrians' needs to follow the shortest possible route. It is advisable to design for tertiary ways during layout planning as this forms the basic link between dwellings.

I.4.2.2 Design strategy

The design strategy could influence the total cost of a pavement structure. The strategy includes the selection of analysis and structural design periods and the important consideration of life cycle analysis. Normally, a design life cycle strategy is applicable only to paved Category U2-B and U3-B roads/streets.

I.4.2.2.1 Analysis and structural design periods

The analysis period is a convenient planning period during which complete reconstruction of the pavement is undesirable. The structural design period, on the other hand, is defined as the period for which it is predicted with a high degree of confidence that no structural rehabilitation or significant maintenance will be required.

In situations where geometric design is expected to be appropriate for longer periods, the analysis period can be as long as 30 years. A shorter analysis period such as 10 years is recommended for uncertain geometric design life, or when substantial changes in the traffic situation are expected. When deciding on a structural design period, various factors should be considered for each category, as summarised below.

(i) Category U2-B and U3-B

A longer structural design period is generally recommended. However, the following factors may encourage a shorter design period:

- A changing traffic situation, which may cause the geometric design to become outdated
- Shortages of funds for the initial construction cost
- A lack of confidence in design assumptions, especially the design traffic

If a shortened structural design period is selected for categories U2-B and U3-B, the design should be able to accommodate a staged construction approach (see Section I.4.2.9.1).

(ii) Category U4-C

If it is expected that structural rehabilitation will be difficult, a long period may be appropriate. For residential streets, a fixed structural design period of 20 years is recommended. Financial constraints may dictate a shorter structural design period of 10 years.

(iii) Category U5-D

Since the traffic volume is limited for this category of streets, a structural design period may not be required. However, the traffic growth can be rapid and unpredictable. A short structural design period enables changes in the initial life cycle strategy to adapt to changing circumstances, without any major financial implication.

(iv) Category U6-E

As these roads are for pedestrian use only, a structural design period may not be applicable.

Table I.6 provides a summary of structural design periods for different street categories.

Table I.6: Structural design periods for various street categories

Functional Class/Category	Structural design period* (years)	
	Range	Recommended
U2-B and U3-B	10-25	20
U4-C	10-30	20

* The analysis period for category U2-B roads/streets is normally 30 years.

I.4.2.2.2 Pavement life cycle strategies

Various alternative designs are initially considered depending on the availability of materials, the structural capacity demand of the actual traffic spectrum and the service level of the facility. The final selection of a particular design depends on an economic analysis, and requires an understanding of the behaviour of different pavement types, and the type and timing of maintenance and rehabilitation during the life cycle as illustrated in Figure I.4. The three scenarios show the generalised trends of riding quality decreasing with time for three different pavement structures as follows:

Design a: Flexible pavement with lower initial construction costs, which requires resurfacing to maintain the condition of the surface, followed by some structural rehabilitation such as an overlay, and later another resurfacing.

Design b: Flexible pavement with reduced future construction costs, which is structurally adequate for the whole of the analysis period and requires only three resurfacing actions.

Design c: Concrete pavement with reduced future construction costs, which is structurally adequate for the whole of the analysis period and does not require resurfacing.

The timing and nature of the maintenance measures can only be estimated when the design strategy is developed. The maintenance programme should be informed by the actual factors once construction has been completed.

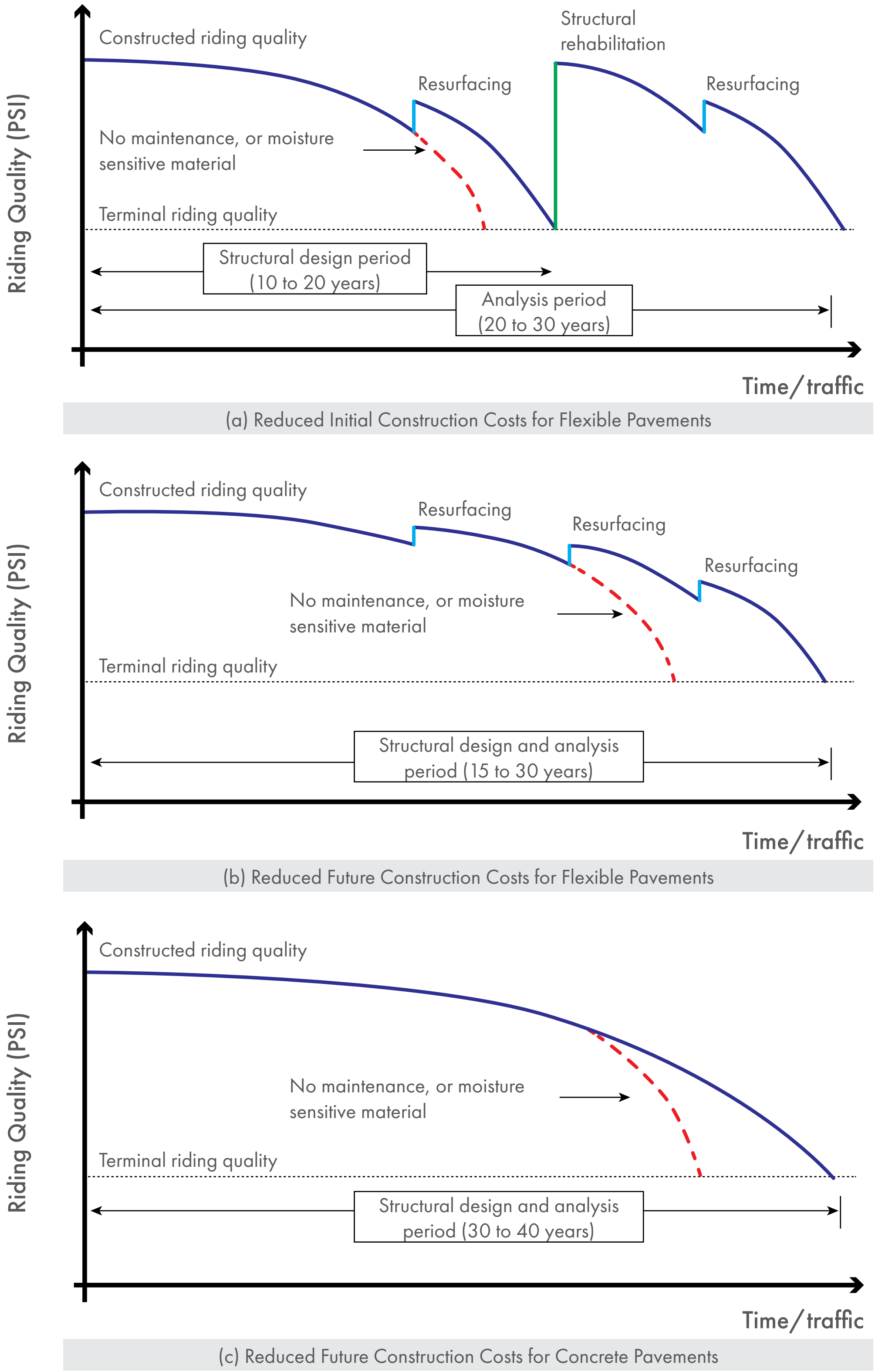


Figure I.4: Illustration of design periods and alternative design strategies

Adapted from SAPEM[17]

I.4.2.3 Design traffic estimates

On determining a design strategy, an estimate should be made of the traffic load to be accommodated in the design. The composition of vehicle traffic on streets varies considerably, ranging from light passenger vehicles to buses and heavy vehicles transporting commercial goods. The composition of the traffic on one street will differ from that on another because of the differences in street functional class or category. The unique traffic spectrum on a particular street will be the design traffic for that street.

The pavement design process focuses on the response of pavements to loading, specifically the volume and loading of heavy vehicles. The extremely variable nature of traffic makes the quantification of traffic loading for a particular road/street complicated. Traffic loading for a particular road/street is influenced by various factors, including shifts in the preferred mode of transport, economic growth, sporadic construction activity, changes to legal axle load limits, changes in the mechanical design and load-carrying capacity of vehicles, the wander of heavy vehicles across the width of the lane (e.g. vehicles used in Bus Rapid Transit (BRT) systems have a much more concentrated wander, and hence causes a greater degree of damage to the pavement), the speed at which heavy vehicles move. The following documents deal with the collection of traffic data and design traffic estimation:

- TRH16 (1991) Traffic Loading for Pavement and Rehabilitation Design
- TMH8 (2014) Traffic and Axle Load Monitoring Procedures
- TMH3 (2015) Specifications for the Provision of Traffic and Weigh-in-Motion Monitoring Service
- TMH14 (2015) South African Standard Automatic Traffic Data Collection Format

I.4.2.3.1 Concepts for design traffic estimation

(i) Legal axle loads

The key factors that play a role in the determination of a legal axle load are vehicle manufacturer's specification, tyre load rating and permitted axle loadings. In South Africa, the static axle mass for different axle groups are set out in TRH16[18] and are based on Regulations 234 to 240 of the Road Traffic Act of 1996.

(ii) Equivalent standard axle loads

The concept of equivalent standard axle load was developed from data that was collected as part of the AASHO Road Test. It is based on the principle that any load may be converted to an equivalent number of standard axle loads, based on the damage done by the load in relation to the damage done by the standard load.

Load sensitivity is generally expressed by the power damage law, often called the 4th power law. The standard axle load for South Africa is a dual-wheel, single-axle load of 80 kN. The Load Equivalency Factor (LEF) of any other load P is calculated using Equation I.1, which is known as the 4th power law if n = 4.

$$LEF = (P/80)^n \qquad \text{Eq I.1}$$

Where:
LEF = Load Equivalency Factor (E80)
P = axle load in kN
n = relative damage exponent (usually 4) (see Table I.7)

The damage exponent n was originally determined as 4.2 from the AASHO Road Test. However, a value of 4 is often used. Pavements that are sensitive to loading, such as those that are shallow-structured with cemented bases, may have n-values of more than 4, whereas less sensitive deep-structured pavements may have n-values typically less than 4. Heavy Vehicle Simulator (HVS) testing in South Africa has shown that depending on the pavement type, pavement balance and distress mechanism, n may vary from 2 to 6, as shown in Table I.7.

Table I.7: Suggested n-values for relative damage exponent (after SAPEM)

Base/Subbase combination		Range of values (Recommended value)
Granular/granular		3 - 6 (4)
Granular/cemented		2 - 4 (3)
Cemented/granular	Pre-cracked	4 - 10 (5)
	Post-cracked	3 - 6 (5)
Cemented/cemented	Pre-cracked	3 - 6 (4 - 5)
	Post-cracked	2 - 5 (4 - 5)
Bitumen Stabilised Material (BSM)/granular		2 - 6 (4)
Hot mix asphalt/cemented		2 - 5 (4)
Concrete		(4.5)

(iii) E80s per heavy vehicles (E80/HV)

An E80/HV is a factor that converts different truck loads to an equivalent number of standard axles. The E80/HV for each vehicle type is, however, not that useful, considering the many different vehicle types on any one route. Therefore, the average E80/HV for a network or section of road is generally used. It should be noted that changes to the legal axle load and the level of enforcement generally affect the E80/HV for a network.

(iv) Daily traffic parameters

Traffic volumes are usually expressed in terms of average daily traffic (ADT) measured in vehicles per day, with the ADT referring to an extended period. Reference is made to Annual Average Daily Traffic (AADT) only if traffic counts are available for a calendar year. When designing road pavements, the traffic averages of heavy vehicles need to be determined in order to calculate axle load. Average Daily E80 (ADE) refers to the average daily E80 per lane per day over the period during which the axle load survey was conducted. Annual Average Daily E80 (AADE) is the total E80 per lane allied during one year divided by 365 days. The AADE cannot be determined from a single survey conducted over a short period of time because of cyclic and random variations in traffic loading that occur during the calendar year. Since axle load surveys are normally conducted over short periods ranging from several days to two weeks, adjustment factors derived from permanent classification count stations are often applied to convert the measured average daily E80 to estimated AADE values.

I.4.2.3.2 Traffic loading classes for structural pavement design

Table I.8 summarises different traffic loading classes, defined in terms of the cumulative equivalent traffic or pavement bearing capacity in the design lane over the structural design period. This definition is used because of the large variation associated with real pavement performance and the associated difficulty in predicting pavement life. Although the traffic classification is useful for communication purposes, the actual equivalent traffic may be required for specific purposes.

Table I.8: Classification of road pavements and traffic loading class for structural design purposes (TRH4)			
Pavement Traffic Loading Class (TLC) i.t.o. number of Equivalent Standard (ES) 80 kN axle loads	Bearing capacity (million 80 kN axles/lane)	Typical traffic volumes and type of traffic	
		Approximate vehicles per day per lane (vpdpl)	Description
ES0.003	< 0.003	< 3	Very lightly trafficked roads/ streets with very few heavy vehicles. Includes roads/ streets transitioning from gravel to paved roads and may incorporate semi-permanent and/or all-weather surfacing layers.
ES0.01	0.003 - 0.01	3 - 10	
ES0.03	0.01 - 0.03	10 - 20	
ES0.1	0.03 - 0.1	20 - 75	
ES0.3	0.1 - 0.3	75 - 220	
ES1	0.3 - 1	220 - 700	Lightly trafficked roads/ streets carrying mainly cars, light delivery and agricultural vehicles with very few heavy vehicles.
ES3	1 - 3	> 700	Medium volume, few heavy vehicles.
ES10	3 - 10	> 700	High volume and/or many heavy vehicles.
ES30	10 - 30	> 2 200	Very high volume of traffic and/or a high proportion of fully laden heavy vehicles
ES100	30 - 100	> 6 500	

It is important to note that road pavement design methods are moving away from using load equivalency and standard axle loads by incorporating the axle load histogram in the design analysis, using an incremental damage approach. The simplest form of this utilises Miner's Law with the current failure criteria. The revised South African Road Design System (SARDS)[19] will incorporate the full traffic spectrum, in which case the E80 may not be used any longer for pavement design.

I.4.2.3.3 Traffic measurement and vehicle classification

(i) Traffic measurement

Traffic counts and classification are done manually or are automated using traffic counting stations installed on the road. Traffic counting is performed on a special or project basis (short-term), or on a temporary (medium-term) to permanent (long-term) basis by road authorities, as part of their road management system data collection strategy. While permanent stations provide a continuous traffic record from one year to the next, temporary stations are used on a sampling or periodic basis to collect data over a specified time period.

(ii) Vehicle classification

The appropriate vehicle classification system depends on the traffic data required and the capabilities of the traffic monitoring equipment. Heavy axle loads, associated with heavy vehicles, do most of the damage on pavements.

For pavement design, traffic should therefore be split between light and heavy vehicles. Based on the length of the vehicle (extended vehicle classification system), heavy vehicles can be classified into three groups that are commonly used for the estimation of pavement design traffic:

- Short heavy vehicle (S): length < 10.8 m
- Medium heavy vehicle (M): length between 10.8 and 16.8 m
- Long heavy vehicle (L): length > 16.8 m

I.4.2.3.4 Traffic investigation for pavement design

An incorrect design traffic estimate results in the same design risk as a pavement structure of inadequate structural capacity. Traffic loading information for pavement design may be obtained from the following sources or methods: Tabulated average E80 values, published results of surveys, transportation planning models, and estimation procedures based on visual observations and project-specific traffic surveys. The level of effort and cost associated with these methods increases from the use of known results to the project specific surveys, but so does the value of the results obtained. The application of each of the above sources or methods is linked to the different categories of road/street, as recommended in Table I.9.

Table I.9: Recommended traffic investigation levels for road functional class/category

Road functional class/ category	Traffic parameter			
	Base year HV volume	HV volume growth rate	Base year E80/ HV	E80/HV growth
U2-B, U3-B	Traffic surveys[1]	Transportation models Published results	Traffic surveys	Published results
U4-C	Visual observation[2]	Published results	Visual observation	Published results
U5-D, U6-E	Published results[3]	Published results	Published results	Published results

[1] Project-specific traffic survey

[2] Project-specific visual observation and tabulated values

[3] Published results, or results from other projects with similar traffic characteristics

I.4.2.3.5 Calculation of design E80

The detailed computation of the design E80 or cumulative equivalent traffic over the structural design period involves the load equivalency of the road/street traffic, surveys of road traffic conditions, projecting the road traffic data over the structural design period and estimating the road lane distribution.

(i) Load equivalency of traffic

The Load Equivalent Factor (LEF) used to calculate the E80 relates the application of any given axle load to the equivalent damage caused relative to the standard axle, which is taken as 80 kN. The LEF is calculated using Equation I.1, as described in Section I.4.2.3.1. Table I.10 provides average equivalency factors based on Equation I.1, with n = 4.

Table I.10: Average Single 80 kN axle equivalency factors, derived from F_{ave} = (P/80)n, with n = 4			
Single axle load, P* (kN)	Average 80 kN axle equivalency factor, F**	Single axle load, P (kN)	Average 80 kN axle equivalency factor, F_{ave}
<15	0.005	115 - 124	5.021
15 -24	0.005	125 - 134	6.916
25 – 34	0.021	135 - 144	9.303
35 – 44	0.064	145 - 154	12.262
45 – 54	0.154	155 - 164	15.876
55 - 64	0.317	165 - 174	20.237
65 - 74	0.584	175 - 184	25.441
75 - 84	0.994	185 - 194	31.590
85 - 94	1.590	195 - 204	38.791
95 - 104	2.422	>205	43.118
105 - 114	3.545		

* Single axle load with dual wheels

** Average is based on LEF = $((P_{lower\ limit}/80)^n + (P_{upper\ limit}/80)^n)/2$

The Average Daily Equivalent (ADE) traffic can be determined by multiplying the number of axle loads (t_i) in each load group in the entire load spectrum by the relevant load equivalency factor (LEF_i).

By summation, the average daily equivalent traffic is calculated using Equation I.2.

$$ADE = \Sigma t_j \, . \, F_j \qquad \text{Eq I.2}$$

A sensitivity analysis should be conducted on the spectrum of loads with n-values as indicated in Table I.7, especially when dealing with abnormal load spectra.

(ii) Surveys of traffic conditions

The present average daily traffic is the amount of daily traffic in a single direction, averaged over the present year. This traffic can be estimated from traffic surveys carried out at some time before the initial year. Such a survey may include static weighing of a sample of vehicles, dynamic weighing of all axles for a sample period (e.g. weigh-in-motion (WIM) survey), or estimation procedures based on visual observation (Table I.11 can be used to assist in this.)

Table I.11: Recommended E80/axle loading for visual observation technique			
Description of Heavy Vehicle Loading	Percentage of Vehicles		Axle Load Factors (E80/axle)
	Fully Laden (%)	Empty or Partially Laden (%)	
Predominantly lightly laden vehicles	< 35	> 45	0.3
Fully laden, partially laden and empty vehicles	40 - 45	34 - 45	0.5
Fully and partially laden vehicles	60 - 75	< 30	0.7
Predominantly fully laden vehicles	> 70		0.9

(iii) Projection of the traffic data over the structural design period

Projection to initial design year:

The present average daily equivalent traffic (daily E80s) can be projected to the initial design year by multiplying by a growth factor determined from the growth rate:

$g_x = (1 = 0{,}01 \times i)^x$ Eq I.3

Where:
g = growth factor
i = growth rate (%)
x = time between determination of axle load data and opening of streets in years

The traffic growth factor (g) is given in Table I.12.

Table I.12: Traffic growth factor (g) for calculation of future or initial traffic from present traffic

Time between determination of axle load data and opening of road, x (years)	*g for traffic increase, i (% per annum)								
	2	3	4	5	6	7	8	9	10
1	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10
2	1.04	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21
3	1.06	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33
4	1.08	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46
5	1.10	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61
6	1.13	1.19	1.27	1.34	1.42	1.50	1.59	1.68	1.77
7	1.15	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95
8	1.17	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14
9	1.20	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36
10	1.22	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59

*$g = (1 + 0.01 \times i)^x$

Computation of cumulative equivalent traffic:

The cumulative equivalent traffic (total E80s) over the structural design period may be calculated from the equivalent traffic in the initial design year and the growth rate for the design period. Where possible, the growth rate should be based on specific information. More than one growth rate may apply over the design period. There may also be a difference between the growth rates for total and equivalent traffic. These rates will normally vary between 2% and 10%, and a value of 6% is recommended.

The Annual Average Daily Equivalent (AADE) traffic in the initial year is given by

$AADE_{initial} = ADE \times g_x$ *Eq I.4*

The cumulative equivalent traffic may be calculated from

$$N_e = AADE_{initial} \times f_y$$ Eq I.5

Where

f_y = cumulative growth factor, based on

f_y = $365\ (1 + 0.01 \times i)[(1 + 0.01 \times i)^y - 1]/(0.01 \times i)$ Eq I.6

(y = structural design prediction period)

The cumulative growth factor (f_y) is given in Table I.13.

Table I.13: Traffic growth factor (f_y) for calculation of cumulative traffic over prediction period from initial (daily) traffic

Prediction period, y (years)	Compound growth rate, i (% per annum) *									
	2	4	6	8	10	12	14	16	18	20
4	1 534	1 611	1 692	1 776	1 863	1 953	2 047	2 145	2 246	2 351
5	1 937	2 056	2 180	2 312	2 451	2 597	2 750	2 911	3 081	3 259
6	2 348	2 517	2 698	2 891	3 097	3 317	3 551	3 801	4 066	4 349
7	2 767	2 998	3 247	3 517	3 809	4 124	4 464	4 832	5 229	5 657
8	3 195	3 497	3 829	4 192	4 591	5 028	5 506	6 029	6 601	7 226
9	3 631	4 017	4 445	4 922	5 452	6 040	6 693	7 417	8 220	9 109
10	4 076	4 557	5 099	5 710	6 398	7 173	8 046	9 027	10 130	11 369
11	4 530	5 119	5 792	6 561	7 440	8 443	9 588	10 895	12 384	14 081
12	4 993	5 703	6 526	7 480	8 585	9 865	11 347	13 061	15 044	17 336
13	5 465	6 311	7 305	8 473	9 845	11 458	13 352	15 575	18 183	21 241
14	5 947	6 943	8 130	9 545	11 231	13 242	15 637	18 490	21 887	25 927
15	6 438	7 600	9 005	10 703	12 756	15 239	18 242	21 872	26 257	31 551
16	6 939	8 284	9 932	11 953	14 433	17 477	21 212	25 795	31 414	38 299
17	7 450	8 995	10 915	13 304	16 278	19 983	24 598	30 346	37 500	46 397
18	7 971	9 734	11 957	14 762	18 308	22 790	28 458	35 625	44 680	56 115
19	8 503	10 503	13 061	16 338	20 540	25 934	32 859	41 748	53 154	67 776
20	9 045	11 303	14 232	18 039	22 995	29 455	37 875	48 851	63 152	81 769
25	11 924	15 808	21 227	28 818	39 486	54 506	75 676	105 517	147 559	206 727
30	15 103	21 289	30 587	44 656	66 044	98 656	148 459	224 533	340 661	517 664
35	18 612	27 858	43 114	67 927	108 816	176 464	288 595	474 509	782 431	1 291 373
40	22 487	36 071	59 877	102 120	177 700	313 586	588 416	999 544	1 793 095	3 216 609

* based on $f_y = 365\ (1 + 0.01 \times i)[(1 + 0.01 \times i)^y - 1]/(0.01 \times i)$

I.4.2.3.6 Estimating the lane distribution of traffic

On multi-lane roads, the traffic will be distributed among the lanes. Note that the distribution of total traffic and equivalent traffic will not be the same. The distribution will also change along the length of street, depending on geometric factors such as climbing or turning lanes. Suggested design factors of equivalent traffic (B_e) are given in Table I.14. As far as possible, these factors incorporate the change in lane distribution over the geometric life of a facility. The factors should be regarded as maxima and decreases may be justified.

The design cumulative equivalent traffic:

The design cumulative equivalent traffic per lane (N_e) may be calculated by multiplying the equivalent traffic by a lane distribution factor (B_e):

$$N_e = E80_{total} = (\Sigma t_j \times F_j) \times g_x \times f_y \times B_e \qquad \text{Eq I.7}$$

Where:

$\Sigma t_j \times F_j$ = equivalent daily traffic at time of survey
g_x = growth factor to initial year (x = period from traffic survey to initial design year)
f_y = cumulative growth factor over structural design period (y - structural design period)
B_e = lane distribution factor for equivalent traffic (see Table I.14)

To check the geometric capacity of the street, the total Annual Average Daily E80 (AADE) traffic towards the end of the structural design period can be calculated from

$$AADE = ADE \times g_x \qquad \text{Eq I.8}$$

with g_x as previously defined.

When projecting traffic over the structural design period, the possibility should be kept in mind that capacity conditions may be reached, which would result in no further growth in traffic for that particular lane.

Table I.14: Design factors for the distribution of equivalent traffic (B_e) among lanes and shoulders

Total number of lanes in both directions	E80 Lane distribution factor			
	Surfaced slow shoulder	Lane 1	Lane 2	Lane 3
2	1.00	1.00	-	-
4	0.95	0.95	0.3	-
3	0.7	0.70	0.6	0.25

Note: Lane 1 is the outer or slow lane

I.4.2.3.7 Design traffic on unpaved roads

For the design of unpaved roads, only the average daily traffic is required, as performance is mostly a function of the total traffic, with the split between light and heavy vehicles being of little importance. This is the result of the traffic-induced deformation of properly designed unpaved streets being restricted to the upper portion of the gravel surfacing. Such problems can be rectified during routine surface maintenance involving grading and spot re-gravelling, or by re-gravelling of the road.

I.4.2.4 Material and pavement selection

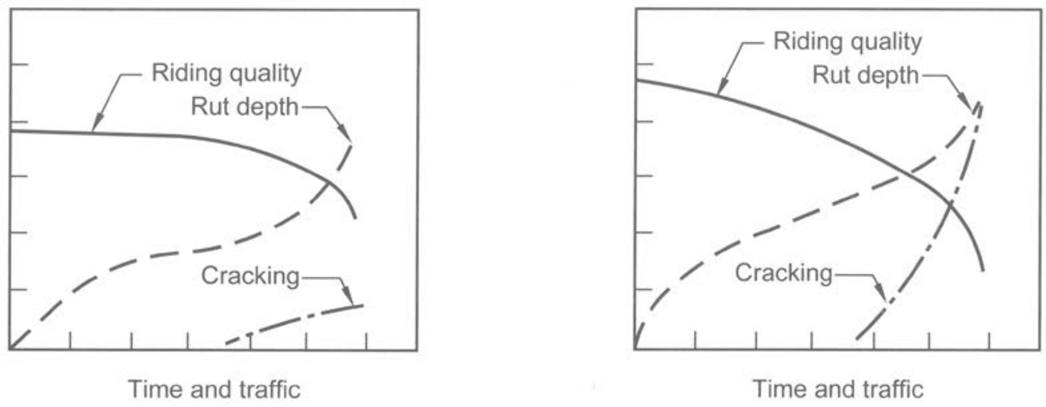
Pavement types and pavement material options are discussed in Section I.3.3. When selecting a pavement type, it is important to understand that the structural behaviour of pavement types differ, especially with respect to the behaviour under loading, the load sensitivity of different pavements, and the pavement behaviour over the long term. A brief description of the typical structural behaviour of different pavement types is given below to guide decision making.

I.4.2.4.1 Flexible pavements

The typical structural behaviours of the four types of flexible pavements commonly used in South Africa are discussed separately.

(i) Unbound granular base pavements

This type of pavement comprises a thin bituminous surfacing, a base of untreated gravel or crushed stone, a granular or cemented subbase and a subgrade of various soils or gravels. The mode of distress in a pavement with an untreated subbase is usually deformation, arising from shear or densification in the untreated materials. The deformation may manifest itself as rutting or as longitudinal roughness, eventually leading to cracking. This is illustrated in Figure I.5(a).



(a) Granular base (b) Bituminous base

Figure I.5: Generalised structural pavement behaviour characteristics - granular base (a); bituminous base (b)

In pavements with cemented subbases, the subbase improves the load-carrying capacity of the pavement, but at some stage the subbase will crack under traffic. The cracking may propagate until the layer eventually exhibits properties similar to those of a natural granular material. It is unlikely that cracking will reflect to the surface, and there is likely to be little rutting or longitudinal deformation until after the subbase has cracked extensively. However, if the subbase exhibits large shrinkage or thermal cracks, they may reflect to the surface.

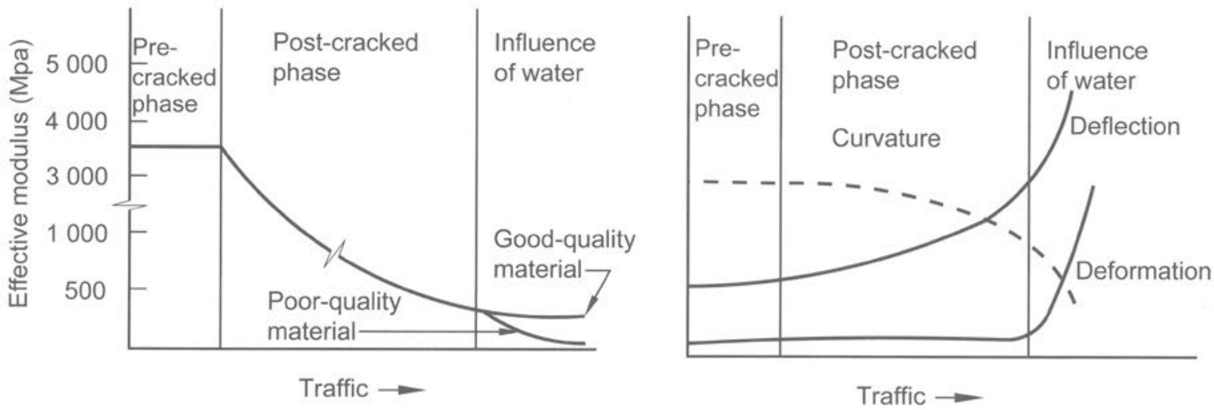
The post-cracked phase of a cement-treated subbase under granular and bituminous bases adds substantially to the useful life of the pavement. Elastic deflection measurements at various depths within the pavement have indicated that the initial effective modulus of this material is relatively high (3 000 to 5 000 MPa) as shown in Figure I.6(a). This relatively rigid subbase generally fatigues under traffic, or in some cases even under construction traffic, and assumes a lower effective modulus (800 to 1 000 MPa). This change in modulus does not normally result in a marked increase in permanent deformation, but the resilient deflection and radius of curvature (RoC) do change, as shown in Figure I.6(b).

In the mechanistic design approach (see **Section I.4.2.6.1**), these phases have been termed the pre-cracked and post-cracked phases. The design accommodates the changes in modulus of the subbase and, although the safety factor in the base will be reduced, it will still be well within acceptable limits. The eventual modulus of the cemented subbases will depend on the quality of the material originally stabilised, the cement agent, the effectiveness of the mixing process, the absolute density achieved, the durability of the stabilisation and the degree of cracking. The ingress of moisture can affect the modulus in the post-cracked phase significantly. In some cases the layer may behave like a good-quality granular material with a modulus of 200 to 500 MPa, but in other cases the modulus may be between 50 and 200 MPa. This change is shown diagrammatically in Figure I.6(a).

The result is that the modulus of the cemented subbase assumes very low values and this causes fatigue and high shear stresses in the base. Generally, surface cracking will occur and, with the ingress of water, there may be pumping from the subbase. Therefore, regular road inspection and maintenance should be executed.

For high-quality, heavily trafficked pavements, it is necessary to avoid materials that will eventually deteriorate to a very low effective layer modulus. Many of these lower-class materials have, however, proved to be adequate for lower classes of traffic.

The surfacing may also crack owing either to hardening of the binder as it ages or to load-associated fatigue cracking. The strength of granular materials is often susceptible to water, and excessive permanent deformation may occur when water enters through surface cracks. The water susceptibility of a material depends on factors such as grading, the plastic index (PI) of the fines, and density. Waterbound macadams are less susceptible to water than engineered crushed-stone base materials and are therefore preferred to be used in the wetter regions of the country.



(a) Cemented-subbase modulus behaviour

(b) Cemented-subbase indicators

Figure I.6: Generalised structural pavement behaviour characteristics - Cemented-subbase modular behaviour (a); Cemented-subbbase indicators (b)

(ii) Hot mix asphalt base pavements

In hot mix asphalt (HMA) base pavements, both permanent deformation (or rutting) and fatigue cracking are possible. Two types of subbase are recommended, namely either an untreated granular subbase or a weakly stabilised cemented subbase. Rutting may originate in either the bituminous or the untreated layers, or in both. This is illustrated in Figure I.5(b). If the subbase is cemented, there is a probability that shrinkage or thermal cracking will reflect through the base to the surfacing, especially if the bituminous layer is less than 150 mm thick or if the subbase is excessively stabilised (~ >5 % cement). Maintenance usually consists of a surface treatment to provide better skid resistance and to seal small cracks, an asphalt overlay in cases where riding quality needs to be restored and when it is necessary to prolong the fatigue life of the base, or recycling of the base when further overlays are no longer adequate.

(iii) Bitumen stabilised base pavements

Although the bituminous binders in emulsion and foam-treated materials are viscous, the material is stiff and brittle, much like a cement-treated material after curing. The initial field stiffness values of these materials may vary between 800 and 2 000 MPa, depending on the bitumen binder content and parent material quality. These values will gradually decrease with increasing traffic loading in these layers to values typical for granular materials roughly between 150 and 500 MPa.

Field performance of pavements with emulsion- and foam-treated base layers indicates that they are not as sensitive to overloading as a pavement with a cement-treated base, and do not pump fines from the subbase during wet conditions under traffic, which is the first mechanism and indication of the formation of potholes in road pavements.

(iv) Cemented base pavements

In these pavements, most of the traffic stresses are absorbed by the cemented layers and a little by the subgrade. It is likely that some block cracking will be evident very early in the life of the cemented bases; this is caused by the mechanism of drying shrinkage and by thermal stresses in the cemented layers. Traffic-induced cracking will cause the blocks to break up into relatively smaller ones. These cracks may propagate through to the surfacing. The ingress of water through the surface cracks may cause the blocks to rock under traffic, resulting in the pumping of fines from the lower layers. Rutting or roughness will generally be low up to this stage, but is likely to accelerate as the extent of the cracking increases, especially in wet conditions. See Figure I.7(a).

Pavements consisting of cemented bases on granular subbases are very sensitive to overloading and to ingress of moisture through the cracks. When both the base and the subbase are cemented, the pavement will be less sensitive to traffic overloading and moisture. The latter type of pavement is generally used. The shrinkage cracks form early in the life of the pavement and should be rehabilitated by proper inspection and surface sealing. Once traffic-load-associated cracking has become extensive, rehabilitation involves either the reprocessing (recycling) of the asphalt base, or the application of a substantial bituminous or granular overlay.

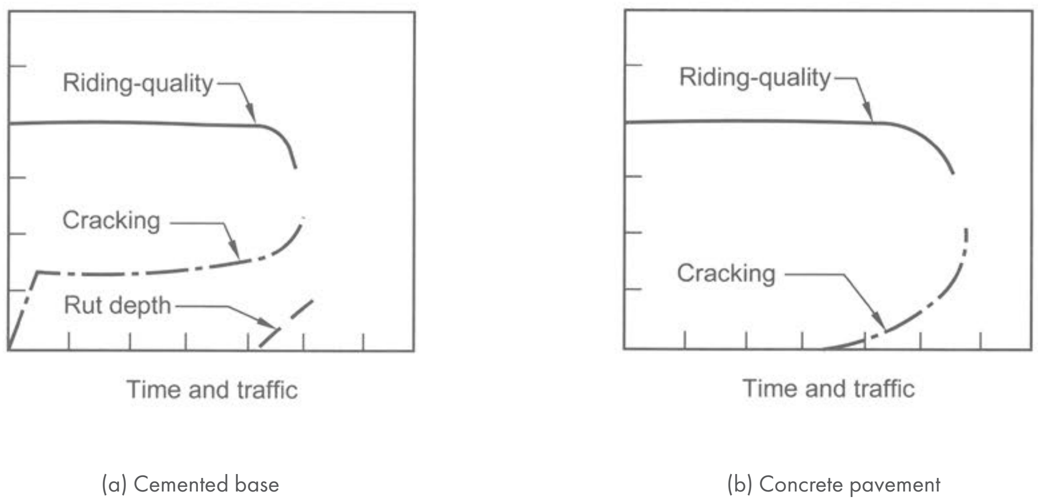


Figure I.7: Generalised structural pavement behaviour characteristics - cemented base (a); concrete pavement (b)

I.4.2.4.2 Rigid pavements

In concrete (rigid) pavements, most of the traffic loading is carried by the rigid concrete slab and little stress is transferred through to the subgrade. The cemented subbase provides a uniform foundation and limits pumping of subbase and subgrade fine materials. Through the use of tied shoulders, most of the distress stemming from the edge of the pavement can be eliminated and slab thickness can also be reduced. Distress of the pavement usually appears first as spalling near the joints, and then may progress to cracking in the wheel paths. Once distress becomes evident, deterioration is usually rapid. See Figure I.7(b). Maintenance consists of patching, joint repair, crack repair, under-sealing, grinding, or thin concrete or bituminous overlays. In cases of severe distress, thick concrete, bituminous or granular overlays will be used, or the concrete may be recycled.

I.4.2.4.3 Semi-rigid pavements

Concrete blocks (semi-rigid pavements) spread concentrated loads over a wide area of earthworks layers. This means that blocks do not merely act as a wearing course, but also as a load-bearing course. The blocks have significant structural capacity when properly installed. The blocks themselves are generally hardly affected by high surface stresses. However, wear or abrasion of the blocks has been observed in some applications. Under traffic, concrete block pavements tend to stiffen, provided the blocks are "locked" in between kerbs or concrete beams on the edges to prevent widening of the joints between the blocks. This leads to the pavements achieving a quasi-equilibrium or 'lockup' condition, beyond which no further deformation occurs. Many types of interlocking and non-interlocking segmental blocks are used in a wide variety of applications, which range from footpaths to driveways to heavily loaded industrial stacking and servicing yards. The popularity of paving blocks is increasing due to a number of factors: the blocks are manufactured from local materials; they can either provide a labour-intensive operation or can be manufactured and laid by machine; they are aesthetically acceptable in a wide range of applications; and they are versatile as they have some of the advantages of both flexible and concrete pavements.

A small plate vibrator is usually used to bed the blocks into a sand bedding of approximately 20 mm thick and also to compact jointing sand between individual blocks. The selection of the right type of sand for these purposes is important, since a non-plastic material serves best as bedding, while some plastic content in the sand is required to fill the joints between blocks.

Properly laid block pavements are adequately waterproofed and ingress of large quantities of water into foundations does not occur. The joints between the blocks on steep gradients may form the drainage paths for rainwater. In such cases the pattern of the blocks is an important consideration. In most cases a herringbone pattern is best for use on steep gradients and for industrial paving. The current recommended minimum strength for structural use is given as a wet compressive strength of not less than 25 MPa.

Block pavements require the paved area to be "contained" either by kerbs or by other means of stopping lateral spread of the block. This is a requirement for both interlocking and non-interlocking shapes. Lateral movements are induced by trafficking and these movements cause breaks in the jointing sand. The associated opening-up of the block pavement makes it more susceptible to the ingress of surface water. In heavily loaded areas, interlocking shapes have advantages over non-interlocking shapes, especially if heavy vehicles with a slewing action are involved.

It is usually recommended that joints should be 2 to 5 mm wide. Geometric design should follow practices for other pavements. Variable street widths, curves and junctions do not present problems in practice, since the blocks are small and can easily be cut and placed to suit the geometry of the pavement. The minimum cross-fall for block pavements should be 1%. For wide areas of industrial paving, special care should be taken to ensure that the cross-fall of the surface is adequate for effective drainage. Cambered cross-sections could also be acceptable under certain conditions.

An advantage of the blocks is that they can be re-used. They can be lifted if repairs have to be done to failed areas of subbase or if services have to be installed and can be re-laid afterwards. As far as the design of segmental block pavements is concerned, this re-use of the blocks has no disadvantages. Little maintenance work is required with segmental block paving. Maintenance involves the treatment of weeds and the correcting of surface levels if the initial construction has been poor. The correction of surface levels is done by removing the area of blocks affected, levelling the subbase, compacting the subbase (often with hand hammers) and replacing the blocks.

I.4.2.4.4 Pavement type selection per road category

Certain road pavement types may not be suitable for some road categories or traffic classes. Table I.15 gives the recommended pavement types for road categories and traffic classes. The availability of material and costs will also influence the selection of pavement type.

Table I.15: Recommended pavement types for road category and traffic class (modified after SAPEM)

Pavement type		Functional class/category & Typical traffic loading class						Reasons for exclusion
		U2-B, U3-B			U4-C, U5-D, U6-E			
Base	Subbase	ES10	ES3	ES1	ES3	ES1	< ES0.3	
Concrete	Granular	Yes	Yes	Yes	Yes	Yes	Yes	Granular subbases prone to erosion at joints and cracks
	Cemented	Yes	Yes	Yes	Yes	Yes	Yes	
Granular	Granular	Yes	Yes	Yes	Yes	Yes	Yes	Uncertain behaviour for high traffic demand
	Cemented	Yes	Yes	Yes	Yes	Yes	Yes	
Hot mix asphalt	Granular	Yes	Yes	No	Yes	No	No	Cost effectiveness
	Cemented	Yes	Yes	No	Yes	No	No	
Cemented	Granular	No	No	No	No	No	Yes	Cracking, crushing, rocking blocks and pumping
	Cemented	No	Yes	Yes	Yes	Yes	Yes	
Bitumen stabilised	Granular	Yes	Yes	Yes	Yes	Yes	Yes	Cost effectiveness, permanent deformation

According to NTR 1 the surfaces along sidewalks are required to be smooth, stable and slip resistant. It is recommended that, along NMT routes, no bevel edge pavers, cobble stones or uneven floor surface finishes, with raised or chamfered edges, be used. All pavers should be installed to be level with an even surface, where no steps exceeding 5 mm occur. Preferred surface finishes include wire-cut clay pavers, wood-floated concrete and tarmacadam.

I.4.2.5 Environmental considerations for pavement design

I.4.2.5.1 Material depth

The term "material depth" is used to denote the depth below the finished level of the road/street up to which soil characteristics have a significant effect on pavement behaviour. Above this depth, the pavement strength must be sufficient for the traffic-imposed stresses. Below this depth, the traffic-imposed stress conditions are assumed to have dissipated and the material quality exceeds strength requirements. The moisture condition above the material depth has a major influence on the material strength, and needs to be controlled by providing adequate surface and subsurface drainage. The material depths recommended for the different road categories for flexible and concrete block pavements are shown in Table I.16. Material depths are normally not considered for concrete pavements, provided that the support is consistent.

Table I.16: Material depths to be used for determining the design California Bearing Ratio (CBR) of the subgrades

Functional class/category	Material depth (mm)
U2-B, U3-B	800 – 1 000
U4-C	800
U5-D, U6-E	700

I.4.2.5.2 Subgrade strength and delineation

A key pavement design principle is that the subgrade should provide an adequate foundation for the pavement layers. The classification of the subgrade material is based on the soaked California Bearing Ratio (CBR) at representative density. A minimum CBR of 15% is generally required for flexible and concrete block pavements.

Any road/street development should be subdivided into significant subgrade areas. However, if the delineation is too fine, it could lead to confusion during construction. The preliminary soil survey should delineate subgrade design units on the basis of geology, pedology, topography and drainage conditions – or major soil boundaries – on site so that an appropriate design CBR for each unit can be defined. A distinction should be made between localised good or poor soils and more general subgrade areas. Localised soils should be treated separately from the rest of the pavement factors. Normally, localised poor soils will be removed and replaced by suitable material. If the strength of a particular subgrade section does not meet the minimum strength requirement, layers of increasing quality are imported to ensure that the minimum strength requirement is achieved. For construction purposes, the design subgrade CBR is classified into four classes (see Table I.17) along with actions to be taken during the construction of pavement foundation. Special measures are necessary if a material with a CBR of less than 3% is encountered within the material depth. These measures include stabilisation (chemical or mechanical), modification (chemical), or the removal or addition of extra cover. After the material has been treated, it will be classified under one of the remaining three subgrade groups. The following should be considered:

- When the road/street is on fill, the best information available on the local materials that are likely to be used should be accessed. The material should be controlled to at least the material depth.
- The design CBR of the subgrade in a cutting should be the 10 percentile CBR encountered within the material depth.

Table I.17: In-situ subgrade delineation for structural design (modified after SAPEM)

Subgrade (SG) class	CBR (%)* of delineated subgrade sections	Action***
SG1	>15	In-situ subgrade of a G7 standard and of sufficient strength to support structural layers • Rip and recompact to 93% of modified AASHTO density
SG2	7 to 15	In-situ subgrade of a G9 standard • Rip and recompact in situ material to 93% of modified AASHTO density • Import a 150 mm thick layer of G7 standard material
SG3	3 to 7	In-situ subgrade of a G10 standard • Rip and recompact in situ material to 93% of modified AASHTO density • Import a 150 mm thick layer of G9 standard material • Import a second 150 mm thick layer of G7 standard material
SG4	<3**	Do one of the following: • Chemical/mechanical stabilisation • Remove and import new material • Add additional cover to place poor quality in situ material below material depth

* CBR at 93% modified AASHTO density
** Special treatment required
*** Material codes G7 and compaction standards from TRH4 (1996) and TRH14 (1987)

For rigid concrete pavements, slab support influences the performance. It is more important to have a uniform slab support than a strong, but variable, support. A strong foundation support is not necessarily required, because of the high stiffness and therefore the good load-spreading ability of concrete.

I.4.2.6 Structural design

The purpose of structural pavement design methods is to provide a method for the unbiased estimate of the structural capacity of alternative design options, to select the most economical option that ensures the traffic demand will be met. A number of design methods of varying complexity are available.

The commonly used methods for the estimation of the structural capacity of flexible, rigid and semi-rigid pavements are discussed below. Other documents, including SANRAL guides, should also be consulted for more details on the methods discussed. The limitations of a particular design method should always be taken into consideration. Most of the purely empirical design methods were developed from data where the design-bearing capacity did not exceed 10 to 12 million standard 80 kN axles. The purely empirical design methods are also limited in their application to conditions similar to those for which they were developed.

It must also be kept in mind that, although these design methods will predict a certain bearing capacity for a pavement structure, there are many factors that will influence the actual bearing capacity of the pavement, and the predicted value should be regarded only as an estimate. It is therefore better to apply various design methods, with each method predicting a somewhat different bearing capacity. This will assist the designer to develop a feeling for the range of bearing capacity for the pavement.

I.4.2.6.1 The design of flexible pavements

(i) The "Catalogue" design method

TRH4 (1996) contains catalogues of candidate road pavement structures for different combinations of pavement type, road category and design structural capacity for flexible pavements. The catalogues contained in TRH4 have been tried and tested, and should be used to benchmark any initial pavement structural design. However, this does not exclude the use of any of the other proven design methods. Consult TRH4 for a catalogue of pavement designs. For the different road materials used in TRH4, consult TRH 14 (1987).

(ii) The Dynamic Cone Penetrometer method

The Dynamic Cone Penetrometer (DCP) method incorporates the concept of a structurally balanced pavement structure in the design procedure. If used properly, designs generated by this method should have a well-balanced strength profile with depth, meaning that there will be a smooth decrease in material strength with depth. Such balanced pavements are normally not very sensitive to overloading. Some knowledge of typical DCP penetration rates for road-building material is required to apply this method.

The DCP method is suitable for the design of light pavement structures with mostly unbound granular or lightly cemented layers, for new and rehabilitation pavement design. DCP design may be done by hand, but if DCP data needs to be analysed, appropriate software has to be used.

(iii) The California Bearing Ratio cover design method

The California Bearing Ratio (CBR) method is based on the principle that the subgrade should be protected from the traffic loading by providing enough cover of sufficient strength. CBR-cover design charts were developed for different subgrade CBR strengths and traffic loadings. The applicability of this method should be evaluated critically before it is applied to local environmental and traffic conditions.

(iv) The AASHTO Guide for Design of Pavement Structures

The *AASHTO Guide for Design of Pavement Structures*[20] provides the designer with a comprehensive set of procedures for new and rehabilitation design and provides a good background to pavement design. This method must be applied with caution for a number of reasons, including the following: The method is an empirical method, based on performance data collected almost 50 years ago; the subgrade and pavement materials, as well as the pavement structures, used in the AASHTO road test are foreign to South Africa; the method is in imperial units and conversion to metric units must be done correctly.

Although some software based on the procedures in the AASHTO design guide is commercially available, the procedure may also be applied manually.

(v) South African Mechanistic Design Method

The South African Mechanistic Design Method (SAMDM) contains ranges of typical resilient modulus and material strength input values and was published for South African road-building materials. Damage models were calibrated for each of the main material groups used in South African road construction.

This SAMDM may be used very effectively for new and rehabilitation design. Some knowledge of the elastic properties of materials as used by the method is required, and experience in this regard is recommended. In the case of rehabilitation design or upgrading, field tests such as the DCP and Falling Weight Deflectometer (FWD) may be used to determine the input parameters for the existing structure.

Access to appropriate computer software is essential for effective use of this method, as well as for analysing DCP and FWD data.

I.4.2.6.2 The design of rigid pavements

The principle of pavement balance does not apply to concrete pavements. The concrete layer thus carries the majority of the applied load, and the distribution of stresses to the lower layers is low. The long-term behaviour of concrete pavements is different for plain jointed, jointed reinforced, or continuously reinforced concrete pavements (CRCPs).

A mechanistic-empirical design method for concrete pavements is implemented in the software package referred to as cncPAVE. cncPAVE is based on the principles used in the 1995 Manual M10 Concrete Pavement Design and Construction, which was developed from the AASHTO method for concrete pavements. cncPAVE was developed as a mechanistic software design tool to design cost-effective rigid concrete pavements.

cncPAVE can quickly assess a design, evaluate its quality and thus facilitate competent decision making. The approach is based on the evaluation of consequences. The consequences of a certain pavement design are expressed in terms of decision variables, namely shattered concrete surface, pumping concrete surface, faulting in the concrete pavement (in the case of plain and dowelled concrete), crack spacing (in the case of continuously reinforced concrete), and life cost of the pavement, in R/m^2. cncPAVE treats input variables and all output items as random variables. cncPAVE is available from the website of The Concrete Institute.[21]

I.4.2.6.3 The design of semi-rigid pavements

The methods for the design of concrete block pavements can be grouped into four categories: the catalogue design method; equivalent thickness concept; research-based design methods; and mechanistic design methods.

For more detailed information on methods available for the design of concrete block pavement, consult *Concrete Block Paving - Book 2: Design Aspects.*[22]

I.4.2.6.4 The design of unpaved roads

Unlike sealed roads, where the application of bituminous surfacing results in a semi-permanent structure (for up to 20 years) in which deformation or failure is costly to repair, unsealed roads are far more forgiving. Routine maintenance is essential and localised problems are rectified relatively easily. The main objectives when designing unsealed roads are to prevent excessive subgrade strain, and to provide an all-weather, dust-free surface with acceptable riding quality. These two objectives are achieved by providing an adequate thickness of suitable material, constructed to a suitable quality. A simple design technique covering gravelling thickness and associated materials has been developed for South Africa and is summarised in *TRH14: Guidelines for road construction materials*, and *TRH 20: The structural design, construction and maintenance of unpaved roads.*

I.4.2.7 Practical considerations

This section discusses some practical considerations regarding road pavements, namely drainage, compaction, pavement cross-sections, road/street levels, and kerbs and channels.

I.4.2.7.1 Drainage

Effective drainage is essential for good pavement performance, hence adequate surface and subsurface drainage should be provided. Drainage design is an integral part of stormwater management and is addressed in Section L (Stormwater). The *Drainage Manual*[23] published by SANRAL provides useful guidelines for drainage design. The following should be considered:

- Attention needs to be paid to subsurface drainage. Effective drainage should be provided to at least the material depth.
- The use of permeable pavements such as porous asphalt has the benefit of improving surface drainage.
- Unpaved roads/streets require side drainage channels that are lower than the street level to ensure that water is drained off the street into the side channels, culverts or pipes.

The longitudinal gradient of a channel and the material used determine the amount of scouring or erosion of such channels. Table I.18 provides the scour velocities for various materials and guidance on the need to line or pave channels.

Table I.18: Scour velocities for various materials

Material	Allowable velocity (m/s)
Fine sand	0.6
Loam	0.9
Clay	1.2
Gravel	1.5
Soft shale	1.8
Hard shale	2.4
Hard rock	4.5

Erosion control is very important to increase the life of road pavements. Control measures should be provided where necessary, especially for tertiary ways. Stormwater must be accommodated by ditches and drains on the sides of the tertiary ways. In Figure I.8, typical detail is given of such ditches and drains. When low points are reached, drifts and dished drains can be used to give preference to the flow of water without major structural requirements. Erosion protection on the approaches must be provided for. Details of typical drifts and dish drains are shown in Figure I.9 to Figure I.14.

Tertiary ways would normally be constructed from the in-situ material. The use of vegetation to prevent erosion is recommended and can be achieved by various means. These should, however, be regularly maintained to avoid a build-up of grass and silt.

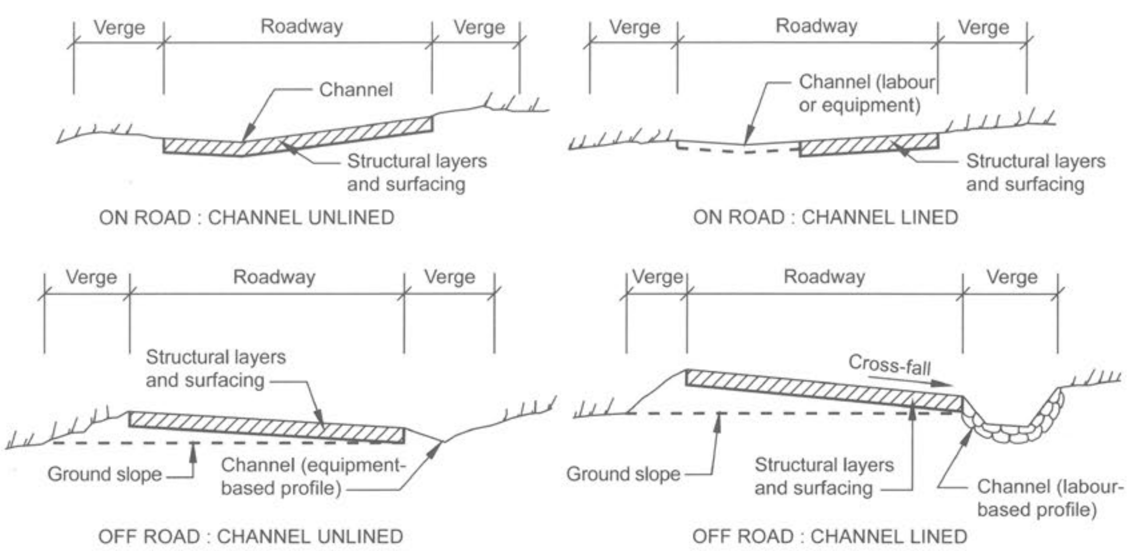


Figure I.8: Typical street cross-sections indicating how stormwater can be accommodated by ditches and drains

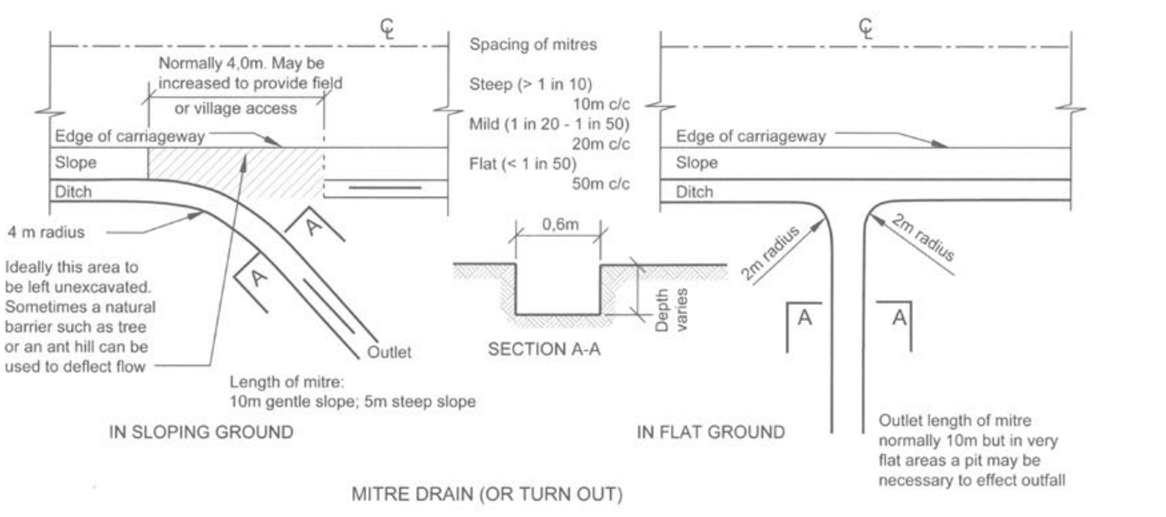


Figure I.9: Tertiary ways: ditches and drains - mitre drain

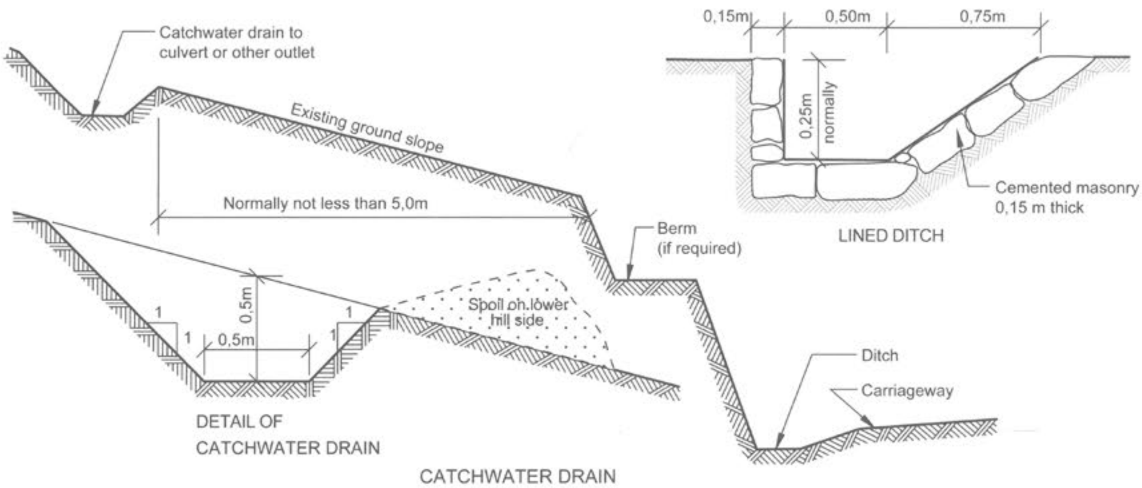


Figure I.10: Tertiary ways: ditches and drains - catchwater drain

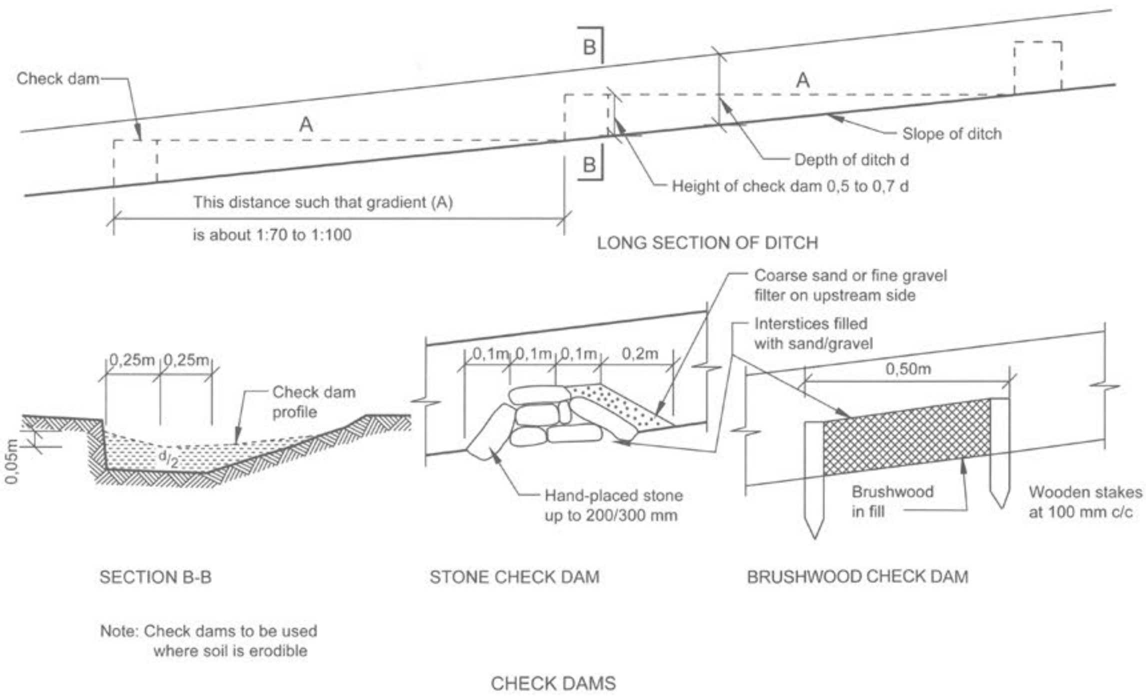


Figure I.11: Tertiary ways: ditches and drains - check dams

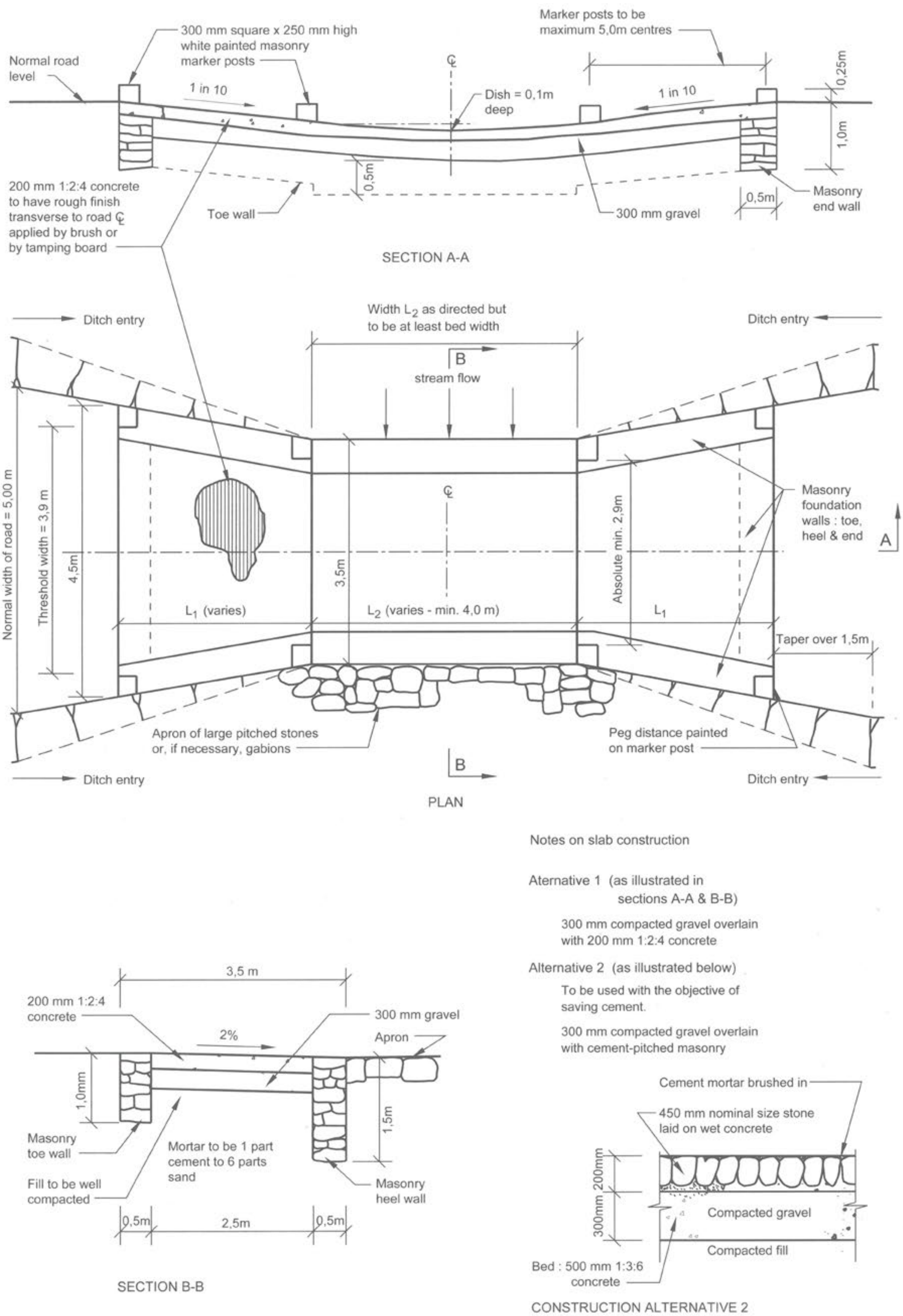


Figure I.12: Tertiary ways: drift

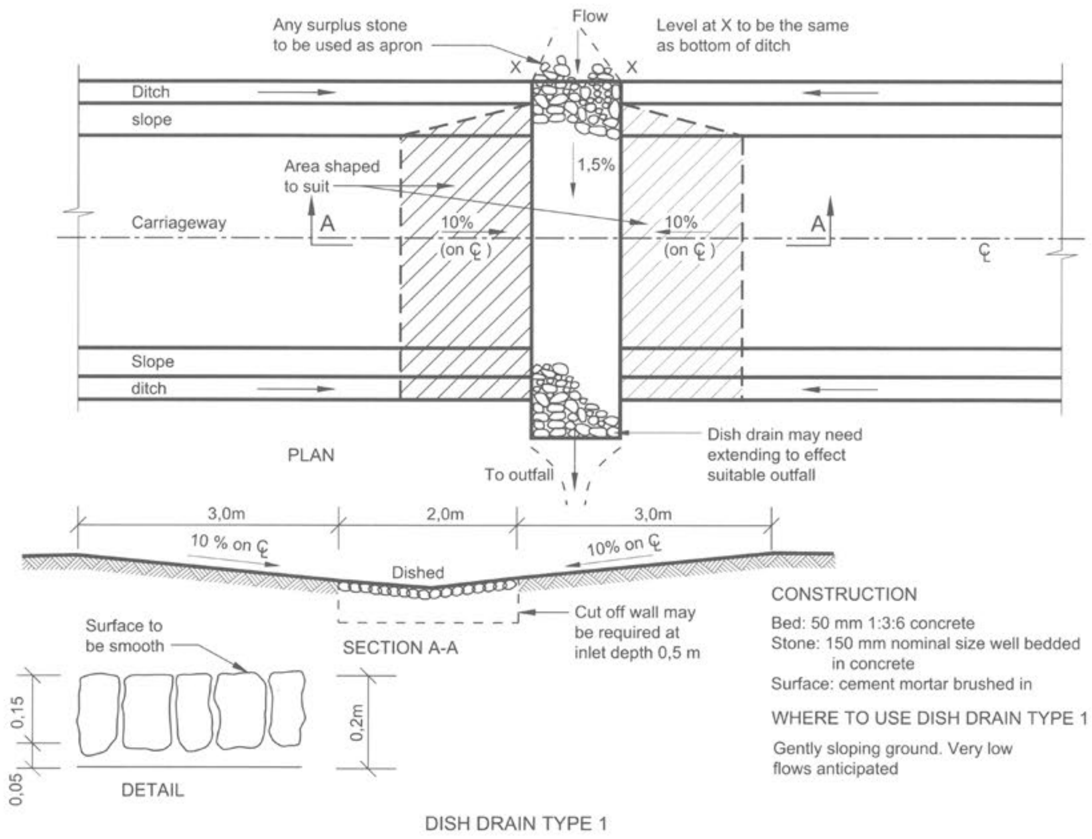


Figure I.13: Tertiary ways: dish drains - type 1

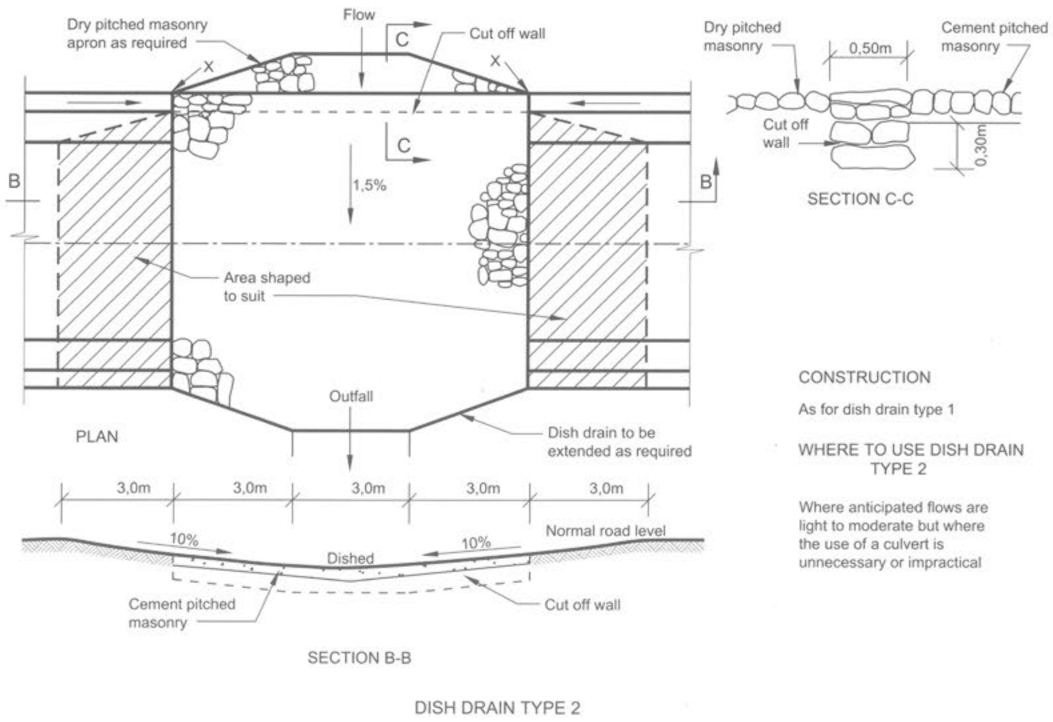


Figure I.14: Tertiary ways: dish drains - type 2

I.4.2.7.2 Compaction of road layers

The design procedures assume that the specified material properties obtained from a certified laboratory are satisfied in the field. Insufficient compaction may result in field densities below the minimum required. In such cases, the strength of the material is not fully utilised, and densification or failure may occur under traffic. The following should be considered:

- Compaction problems may result from material grading deficiencies or poor construction practices.
- Blending of material from different sources to improve the grading and compaction potential of the material may be better than trying to achieve density with excessive rolling.
- When compacting a layer, the support layer needs sufficient support to act as an anvil, otherwise the compaction energy is transmitted and lost through the pavement structure.
- The use of impact rollers can improve the strength and support from the subgrade substantially. Hand-held rollers may be inadequate to achieve the required density.

Table I.19 gives the minimum compaction standards required for various layers of the pavement structure. For detailed compaction standards for various material, other relevant documents such as TRH 14 (1985) and COTO should be consulted.

Table I.19: Compaction requirements for the construction of granular and cemented pavement layers (and reinstatement of pavement layers)

Pavement layer/Material		Compacted density
Surfacing	Asphalt	93% to 94% MVD
Base	Crushed stone G1	86% to 88% AD
	Crushed stone G2	100% to 102% MDD
	Crushed stone G3	98% to 100% MDD
	Waterbound macadam	86% to 90% AD
	Natural gravel G4	86% to 88% MDD
	Cemented (C3/C4)	97% to 98% MDD
	BSM	97% to 100% MDD
	Asphalt	96% MVD
Subbase	Natural gravel	95% to 97% MDD
	Cemented (C3/C4)	95% to 96% MDD
Selected subgrade	Soils and gravel	93% to 95% MDD
Subgrade	Soils and gravel	90% MDD
Fill (cohesionless sand)		90% MDD

Note: MVD = Maximum Voidless Density (see SABITA Manual 35/TRH 8); AD = Apparent Density; MDD = Maximum Dry Density.

I.4.2.7.3 Pavement subgrade

Generally, it is preferable to keep the design of the whole street the same, with no change in layer thickness across the road/street. However, the pavement cross-section may vary if problematic subgrade conditions (i.e. expansive clay) are encountered, hence requiring special treatment. The main subgrade problems that have to be considered include the extreme changes in volume that occur in some soils as a result of moisture changes (e.g. in expansive soils and soils with collapsible structures); flaws in structural support (e.g. sinkholes, mining subsidence and slope instability); the non-uniform support that results from wide variations in soil types or states; the presence of soluble salts which, under favourable conditions, may migrate upwards and cause cracking, blistering or loss of bond of the surfacing; disintegration of cemented bases and loss of density of untreated bases; and the excessive deflection and rebound of highly resilient soils during and after the passage of a load (e.g. in ash, micaceous and diatomaceous soils).

I.4.2.7.4 Road/Street levels

One of the primary functions of a road/street is to provide access to dwellings and other land uses. To optimise accessibility, the design of road/street levels should consider that road/street levels place some restrictions on rehabilitation and create special moisture/drainage conditions. In some cases, rehabilitation in the form of an overlay may cause a problem, particularly with respect to the level of kerbs and channels, camber and overhead clearances. In these cases, strong consideration should be given to bottom-heavy designs (i.e. designs with a cemented subbase and possibly a cemented base), which would mainly require the same maintenance as thin surfacings and little structural maintenance during the analysis period.

I.4.2.7.5 Service trenches

Trenches excavated in the pavement to provide essential services (electricity, water, telephone, etc.) are frequently a source of weakness in the structural design. This is a result of either inadequate compaction during reinstatement, or saturation of the backfill material. Service trenches can also be the focal points of drainage problems. To minimise problems related to service trenches, compaction must achieve at least the minimum densities specified for various materials. These densities are readily achieved when granular materials are used, but it becomes more difficult when natural materials are used, particularly in the case of excavated clays. When dealing with clay subgrades it is recommended to, if economically feasible, use a moderate-quality granular material as a trench backfill in preference to the excavated clay. The provision of a stabilised “cap” over the backfill may be considered to eliminate settlement as far as possible. Care must be taken not to over-stabilise (i.e. produce a concrete), as this results in significant problems with adhesion of the surfacing and differential deflections causing failure around the particles.

Settlement in the trench, giving rise to standing water and possibly to cracking of the surface, will permit the ingress of moisture into the pavement. Fractured water, sewerage or stormwater pipes lead to saturation in the subgrade and possibly in the pavement layers as well. Alternatively, a trench backfilled with granular material may even act as a subsurface drain, but then provision for discharge must be made. It is, however, generally recommended that the permeability of the backfill material should be as close as possible to that of the existing layers in order to retain a uniform moisture flow regime within the pavement structure.

I.4.2.7.6 Kerbs and channels

Kerbs and channels are important to prevent edge erosion and to confine stormwater to the street surface. Consideration should be given to the type and method of construction of kerbs when deciding on a layer thickness for the base. It is common practice to construct kerbs upon the (upper) subbase layer to provide edge restraint for a granular base. This restraint will help to provide the specified density and strength. Care must be taken to ensure that this type of structure does not “box” moisture into the base course material. In the case of kerbing with a fixed size (i.e. precast kerbing or kerbing with fixed shutters cast in situ), it may be advantageous to design the base thickness to conform with the kerb size (e.g. if the design calls for a 30 mm AG with a 125 mm G4 underlay, and the gutter face is 160 mm, rather use a 130 mm G4).

I.4.2.8 Cost analysis

This section discusses how doing a cost analysis can assist the designer in selecting the optimal pavement type for a development project. The selection of the final pavement design is based on the life cycle assessment of a number of alternative designs. The purpose of the structural design method is therefore not the selection of the final design, but to provide the designer with a number of design alternatives with the required structural capacity. It should, however, be noted that a cost analysis may not take all the necessary factors into account and it should therefore not override all other considerations. Financial affordability should also be considered. The availability of funds for the initial construction, and the availability of maintenance funds must be considered, as these could influence the final design decision. The designer should consult TRH4, TRH12 and other relevant guideline documents for detailed information on cost analysis.

The main economic factors that determine the cost of a facility are the analysis period, the structural design period, the construction cost, the maintenance cost, the salvage value at the end of the analysis period and the real discount rate. The cost comparison of alternative pavement designs for a specific design case can be done using the Present Worth of Cost (PWOC), the Net Present Value (NPV) or the Internal Rate of Return (IRR) of the initial construction and anticipated maintenance and rehabilitation costs. The PWOC method is briefly discussed next.

I.4.2.8.1 The Present Worth of Cost method

The PWOC method of cost analysis is recommended in this Guide, and should be used only to compare pavement structures in the same road/street category. This is because roads/streets in different categories are constructed to different standards and are expected to perform differently, with different terminal levels of service. The effect these differences have on street user costs is not taken into account directly. Although the economic principles presented in this document refer to flexible pavements, the same economic principles apply for concrete. A complete cost analysis should be done for functional classes/categories U2-B and U3-B roads/streets. For functional classes/categories U4-C to U6-E roads/streets, a comparison of the construction and maintenance costs will normally suffice. A difference in the economic indicator between two alternative designs of less than 10% is insignificant, and the designs are assumed to be equivalent in economic terms.

The total cost of a project over its life is the construction cost plus maintenance costs, minus the salvage value.

The present worth of costs can be calculated as follows:

$$PWOC = C + (M_1 (1 + r)^{-x_1} + \ldots + M_j (1 + r)^{-x_j}) + \ldots - S(1 + r)^{-z} \qquad \text{Eq I.9}$$

Where:

$PWOC$ = present worth of cost
C = present cost of initial construction
M_1 = cost of the j^{th} maintenance measure expressed in terms of current costs
r = real discount rate
x_j = number of years from the present to the j^{th} maintenance measure, within the analysis period
z = analysis period
S = salvage value of pavement at the end of the analysis period, expressed in terms of the present value

The construction cost should be estimated from current contract rates for similar projects. Maintenance costs should include the cost of maintaining adequate surfacing integrity (e.g. through resealing) and the cost of structural maintenance (e.g. the cost of an asphalt overlay). The salvage value of the pavement at the end of the analysis period can contribute to the next pavement. However, geometric factors such as minor improvements to the vertical and horizontal alignment and the possible relocation of drainage facilities make the estimation of the salvage value very difficult. The choice of analysis period and structural design period will influence the cost of a road/street. The final decision will not necessarily be based purely on economics, but will depend on the design strategy.

(i) Construction costs

The checklist of unit costs should be used to calculate the equivalent construction cost per square metre. Factors to be considered include the availability of natural or local commercial materials, their expected cost trends, the conservation of aggregates in certain areas, and practical aspects such as speed of construction and the need to foster the development of alternative pavement technologies. The potential for labour-based construction also needs to be considered. The cost of excavation should be included as certain pavement types will involve more excavation than others.

(ii) Maintenance costs

There is a relation between the type of pavement and the maintenance that might be required in the future. When different pavement types are compared on the basis of cost, these future maintenance costs should be included in the analysis to ensure that a sound comparison is made. This is critical for the planning of future maintenance activities.

It is important to consider that relaxations of material, drainage or pavement thickness standards will normally result in increased maintenance costs. The type of surfacing and water ingress into the pavement also plays an important part in the behaviour of some pavements. For this reason, planned maintenance of the surfacing is very important to ensure that these pavements perform satisfactorily. The service life of each type of surfacing will depend on the traffic and the type of base used.

Table I.20 gives guidelines regarding the service life that can be expected from various surfacing types. These values may be used for a more detailed analysis of future maintenance costs. Typical maintenance measures that can be used for the purpose of cost analysis are measures to improve the condition of the surfacing and structural maintenance measures applied at the end of the structural design period. Maintenance will also be influenced by the level of distress of the pavement (moderate or severe).

Other road/street-user costs should also be considered, although no proper guide for their determination is readily available. The factors that determine overall road/street-user costs are: running costs (fuel, tyres, vehicle maintenance and depreciation), which are largely related to the street alignment, but also to the riding quality (PSI); accident costs, which are related to street alignment, skid resistance and riding quality; and delay costs, which are related to the maintenance measures applied and the traffic situation on the streets.

Table I.20: Suggested typical ranges of period of service of various surfacing types (modified from SAPEM)

Base type	Surfacing type (50 mm thickness)	Typical range of surfacing life (years) per functional class/category	
		U2-B, U3-B (ES1-ES10)	U4-C, U5-D, U6-E (ES0.003-ES3)
Granular	Bitumen sand or slurry seal	-	2-8
	Bitumen single surface treatment	6-10	8-11
	Bitumen double surface treatment	6-12	8-13
	Cape seal	10-12	8-18
	Continuously graded asphalt	-	-
	Gap-graded asphalt premix	-	-
Hot mix asphalt	Bitumen sand or slurry seal	-	2-8
	Bitumen single surface treatment	6-10	8-11
	Bitumen double surface treatment	6-12	8-13
	Cape seal	8-15	8-18
	Continuously graded asphalt	8-12	-
	Gap-graded asphalt premix	10-15	-
	Porous asphalt	10-15	-
Cemented	Bitumen sand or slurry seal	-	-
	Bitumen single surface treatment	4-7	5-8
	Bitumen double surface treatment	5-8	5-9
	Cape seal	5-10	5-11
	Continuously graded asphalt	5-10	-
	Gap-graded asphalt premix	6-12	-

- Surface type not normally used.

(iii) Real discount rate

When a 'present-worth' analysis is done, a real discount rate must be selected to express future expenditure in terms of present-day values. This discount rate should correspond to the rate generally used in the public sector. For public projects, the discount rate used is published by the National Treasury. 8% is recommended for general use. A sensitivity analysis using rates of say 6, 8 and 10% could be carried out to determine the importance of the value of the discount rate.

(iv) Salvage value

If the road/street is to remain in the same location, the existing pavement layers may have a salvage value but, if the road/street is to be abandoned at the end of the period, the salvage value could be small or zero. The assessment of the salvage value can be approached in a number of ways, depending on the method employed to rehabilitate or reconstruct the pavement.

The salvage values of individual layers of the pavement may differ considerably, from estimates as high as 75% to possibly as low as 10%. The residual salvage value of gravel and asphalt layers is generally high, whereas that of concrete pavements can be high or low, depending on the condition of the pavement and the method of rehabilitation. The salvage value of the whole pavement would be the sum of the salvage values of the individual layers. In the absence of better information, a salvage value of 30% of initial construction cost is recommended.

(v) Optimisation of life cycle costs

The main purpose of the determination of a representative Level of Service (LoS) for a road/street (see **Section I.4.2.1**) is to illustrate the associated life cycle costs. This identification can enable authorities and decision makers to select a design that will be affordable and upgradable. The costs associated with a typical road/street are made up of design and construction costs, maintenance costs and road/street-user costs. Construction costs are high for high LoS values and low for low LoS values. Maintenance costs, on the contrary, are low for high LoS values and high for low LoS values.

This concept is illustrated in Figure I.15 with typical, present worth-of-cost versus LoS values. The combined cost curve has a typical minimum value between the highest and lowest LoS values. Street-user costs are low for high LoS streets and high for low LoS streets.

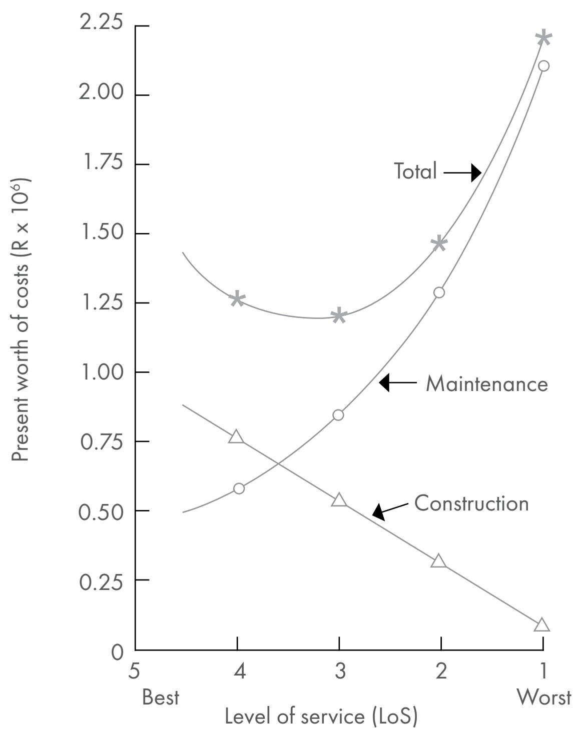


Figure I.15: Typical cost versus level of service curve values

I.4.2.9 Construction aspects

I.4.2.9.1 Staged construction and upgrading

Two concepts that need to be considered as part of the life cycle strategy of a street during design are staged construction and upgrading. Although it is difficult to exactly define and completely separate these concepts, certain characteristics may be more typical of one than of the other.

The aim of staged construction is to spread some of the financial load from the initial construction period to some stage later during the life cycle of the facility. However, right from the onset, the aim is to provide a particular level of service for the duration of the structural design and analysis period of the facility. There may be slight changes in, for instance, the riding quality of the facility, but these should have a marginal influence on the operating cost of the facility to the user. On the other hand, upgrading will normally take place when the demands placed on an existing facility far exceed the level of service the facility can provide. The new facility has to provide a much higher level of service at a much reduced cost to the user. An example would be the upgrading from a gravel to a surfaced street.

Staged construction may be done by adding a final layer, or reworking an existing layer at some stage early during the structural design period of the facility. Most of the money spent during the initial construction of the facility should therefore be invested in the lower layers of the structure, providing a sound foundation to build on in the future.

During the upgrading process, maximum use should be made of the existing foundation provided by the pavement being upgraded. Dynamic Cone Penetrometer (DCP) and Falling Weight Deflectometer (FWD) surveys may provide the information required to incorporate the remaining strength of the existing pavement in the design of the future facility. Special equipment may also be used to maximise the bearing capacity of the in-situ material. With impact roller equipment, it is usually possible to compact the in-situ material to a depth of 600 mm at densities well above those normally specified for the subgrade and selected layers of a pavement, without excavating and replacing any material. This results in few layers or thinner layers being required in the pavement structure.

One of the problems that may be associated with staged construction is the limitation placed on street levels by the other services in the street reserve, particularly the stormwater drainage system. If a system of kerbs, gutters and stormwater pipes is used, it may not be possible to add an additional structural layer to the pavement system at a later stage. In such cases, consideration should be given to initially providing a subbase-quality gravel base, and to rework this layer at some early stage in the structural design period of the pavement by doing deep in-place recycling and stabilisation with cement, bitumen emulsion or a combination of the two. A second problem that requires consideration is the cost of repeated mobilisation on a project. The mobilisation of plant and resources for a light pavement structure in an urban area (usually of short length) is often a significant portion of the total cost.

In general, staged construction spreads the financial burden of construction and is economically more viable than initial full construction. The economics of each project must, however, be considered on merit. It must also be kept in mind that because some of the cost of construction is shifted a few years into the life cycle of a pavement, future budgets must allow for this cost plus inflation.

The details of upgrading from a gravel street to a surfaced street will depend largely on individual projects and will be determined by the bearing capacity of the material on the existing street. As already mentioned, the strength of the existing pavement should be optimally utilised in the new design and if material is imported to the gravel street, the possible utilisation of this material in a future upgrading to a paved street should be kept in mind. The cost analysis for upgrading from a gravel to a surfaced street must at least include the savings in vehicle-operating cost as part of the benefit to the street user. The cost of upgrading should be weighed against the benefits by means of a cost-benefit analysis, expressing the benefits as a ratio to the cost. Software is available for this type of analysis.

I.4.2.9.2 Construction approaches

Construction of streets within settlements has become a highly mechanised process but, over the past few years, the possibility of creating employment opportunities has led to greater use of labour-intensive technologies. Local people are often appointed as subcontractors to established contractors or as contractors for small projects.

These initiatives have not only contributed to local economic development and the transfer of skills, but have also contributed to the successful completion of construction projects by providing local knowledge and getting buy-in from local communities.

A choice between conventional construction (mechanised) and labour-intensive construction may have some impact on the selection of materials and the structural design of the pavement.

Conventional construction is suited to most new street construction assignments, perhaps with the exception of construction in confined areas. Advantages may include rapid mobilisation and completion, while disadvantages may include limited involvement of the local community.

In order to ensure the maximisation of job creation to the extent that it is economic and feasible, the terms of reference for technical consultants engaged to carry out feasibility studies should require the consultant to examine the appropriateness of designs that are inherently labour intensive; to report on the economic implications of using such designs; and to ultimately design a project based on designs and technology appropriate for construction that maximises labour-intensive methods.

Labour-intensive construction should strive to obtain the standards set for conventional construction. However, the design should ensure that the standards specified are appropriate. This necessitates a critical review of all specifications during the design stage.

All construction activities cannot always be executed by means of labour-intensive methods. This must be recognised in the design. Examples of activities demanding greater mechanisation are the following:

- Deep excavation (apart from safety considerations, material can only be thrown a certain height by shovel)
- Excavation and spreading of very coarse material
- In-situ mixing of stabilising material (cement or lime) effectively into coarse aggregates
- Application of tar (due to safety considerations)
- Compaction of thick layers or very large aggregates (e.g. rock fill) with small (pedestrian) rollers
- Mixing of high-strength concrete
- Excavation of medium to hard material
- Haulage by wheelbarrows over long distances
- Placement of heavy pipes

To investigate the potential for employment creation through construction, it is useful to select the construction activities that have the biggest impact on employment creation (where the contribution of this activity forms a significant part of the project cost and the activity has the potential for employment creation). Table I.21 provides an indication of the relative contribution of the main construction activities to the total project cost. A preliminary cost analysis can be done. It is further necessary to consider using a local plant and materials (i.e. rent plant and purchase material from the community).

The result of this investigation may indicate that some activities cannot be done by means of manual labour, due to construction practicalities or the availability of materials. A more detailed cost analysis can then be done. Make sure that the design can be specified.

Table I.21: Relative contribution of main activities

Description	% contribution towards project costs		
	Rehabilitation	Paved	Gravel
Site accommodation	3	2	4.5
Accommodation of traffic	5	5	4
Clearing and grubbing	0.5	1	2
Drainage	3	3	7.5
Culverts	3	15	11
Kerbs and edging	3.5	8.5	0
Earthworks	6	4	22
Pavement layers	10	14	16
Base	8	10	0
Prime and seal work	35	15	0
Ancillary works	5	4	6.5
Landscaping	2	1	1.5

Table I.22 illustrates the potential of one of these main activities (pavement layers) for using labour-intensive methods.

Table I.22: Potential of pavement layers for labour-intensive construction methods

Layer	Type	Potential
Subbase	In-situ soil Imported Stabilised soil	Good Good* Fair, not practical
Base	In-situ soil Natural gravel Emulsion-treated gravel Crusher run Cement-stabilised gravel Lime-stabilised gravel Bituminous premix Waterbound macadam Penetration macadam	Good Good Good Fair, not practical Not practical** Fair, good*** Fair, good Good Good
Surfacing	Sand seal Slurry Double seal Cape seal Asphalt Roller-compacted concrete Concrete (plain) Concrete (reinforced) Segmental blocks	Good# Good Good# Good# Fair Good Good Good Good##

Notes:

* The suitability of this will depend entirely on the haul distance.

** Cement-stabilised gravel is not suitable for labour-intensive methods due to its quick setting time.

*** Lime-stabilised gravel is more suitable as it reacts and sets more slowly, but achieving an even mix is difficult by entirely manual means and labourers must take extreme care to avoid contact between the lime and skin during application. Protective clothing is essential.

In the case of bitumen surfacing, only certain types of emulsion have a non-critical application temperature and are suitable for hand laying.

Quality control of on-site manufacture is critical.

A further breakdown of possible activities that are labour-intensive in road pavement construction is provided in Table I.23.

Table I.23: Typical labour-intensive activities

Component	Activities
Accommodation of traffic	Watering of gravel diversions
Clearing and grubbing	As required
Drainage	Catch pits and manholes
	Excavation of open drains
	Lined open drains
	Subsoil drains
Culverts	Inlet and outlet structures
	Excavation of trenches
	Installation of lightweight pipes
	Manufacture of reinforced concrete slabs, walls and decks
	Masonry walls
Kerbing and edging	Manufacture of concrete elements
	Laying of kerbing and edging
Earthworks	Minor earthworks
Pavement layers	Crushing of aggregates
	Screening of stockpiles
	Haulage of materials
	Spreading of materials
	Removal of oversize materials
Base	Construction of labour-intensive base types (waterbound macadam, emulsion-treated base, stabilised or un-stabilised gravel)
	Manufacture of paving blocks
	Laying of paving blocks
Prime and seal work	Hand spraying of prime
	Manufacture and laying of slurry
	Seals (Cape seal, double seal, single seal)
Ancillary works	Fencing
	Masonry walls
	Gabions
	Concrete structures
	Painting of road markings
Landscaping	Grassing
	Planting of trees

Glossary, acronyms, abbreviations

Glossary

AASHO Road Test
The AASHO (American Association of State Highway Officials) Road Test was a series of experiments carried out in the 1950s by the American Association of State Highway and Transportation Officials (AASHTO) to determine how traffic contributed to the deterioration of highway pavements.

Annual Average Daily E80 (AADE)
The annual average daily is the total E80 per lane allied during one year divided by 365 days. The AADE cannot be determined from a single survey conducted over a short period of time because of cyclic and random variations in traffic loading which occur during the calendar year. Since axle load surveys are normally conducted over short periods ranging from several days to two weeks, adjustment factors derived from permanent classification count stations are often applied to convert the measured average daily E80 to estimated AADE values.

Average Annual Daily Traffic (AADT)
The average annual daily traffic includes all vehicles and all directions. The total year's traffic is divided by 365 days. Heavy vehicles are often given as a percentage of the AADT or ADT.

Average Daily E80 (ADE)
The average daily E80 per lane per day over the survey period during which the axle load survey was conducted.

Average Daily Traffic (ADT)
The average daily traffic includes all vehicles (light and heavy) travelling in all directions.

E80
The standard axle load used in South Africa is 80 kN (approximately 8 165 kg), and the damage caused by any other axle load relative to the standard axle is defined as the equivalent standard axle, or E80.

Acronyms and abbreviations

AADT	Average Annual Daily Traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transport Officials
ADE	Average Daily E80
ADT	Average Daily Traffic
BRT	Bus Rapid Transit
BSMs	Bitumen Stabilised Materials
CBR	California Bearing Ratio
CITP	Comprehensive Integrated Transport Plan
COTO	Committee of Transport Officials

CRCP	Continuously Reinforced Concrete Pavements
DCP	Dynamic Cone Penetrometer
DJCP	Doweled Jointed Concrete Pavement
EVU	Equivalent Vehicle Units
HMA	Hot mix asphalt
IDP	Integrated Development Plan
JCP	Jointed Concrete Pavement
LEF	Load Equivalency Factor
LoS	Level of Service
NATMAP	National Transport Master Plan
NMT	Non-motorised Transport
PWOC	Present Worth of Cost
RA	Reclaimed Asphalt
SABITA	Southern African Bitumen Association
SABS	South African Bureau of Standards
SAMDM	South African Mechanistic Design Method
SANRAL	South African National Roads Agency
SAPEM	South African Pavement Engineering Manual
SARDS	South African Road Design System
TLC	Traffic Loading Class
TMH	Technical Methods for Highways
TRH	Technical Recommendations for Highways
UTRCP	Ultra-Thin Reinforced Concrete Pavement

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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
Water supply

The Neighbourhood Planning and Design Guide

Table of contents

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.

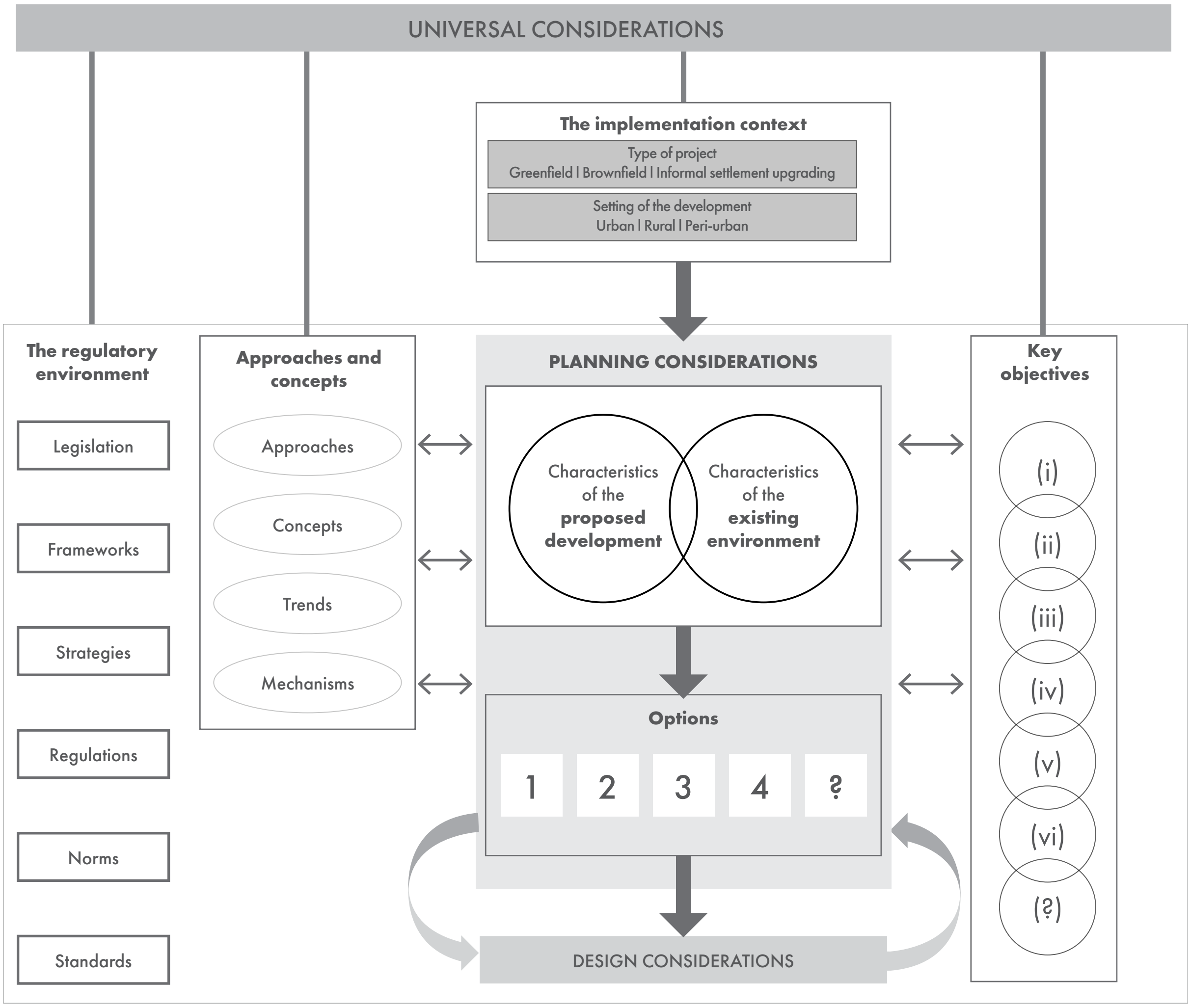


Figure J.1: A framework to assist with planning and design decisions

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]

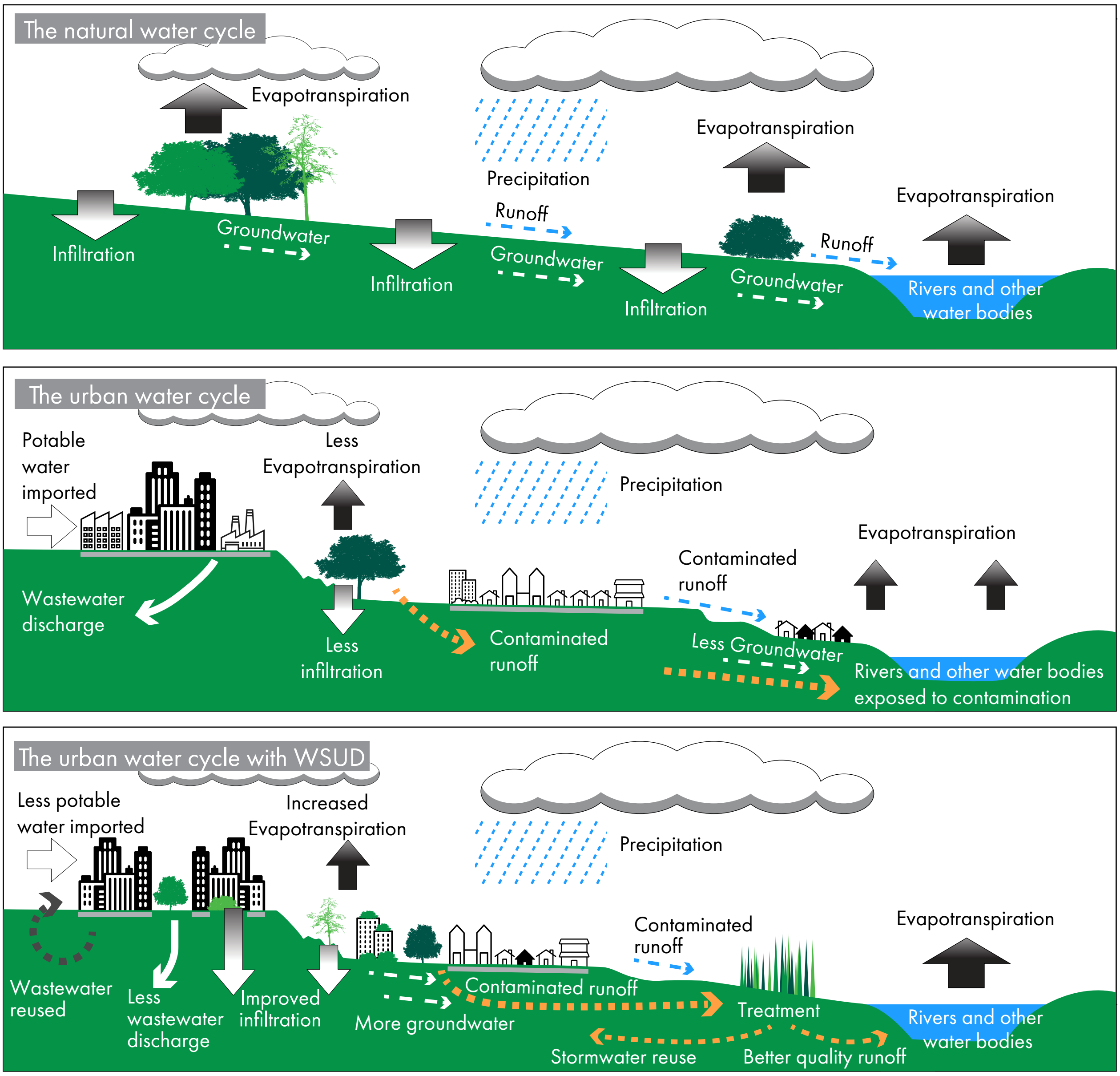


Figure J.2: The water cycle under different conditions

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.

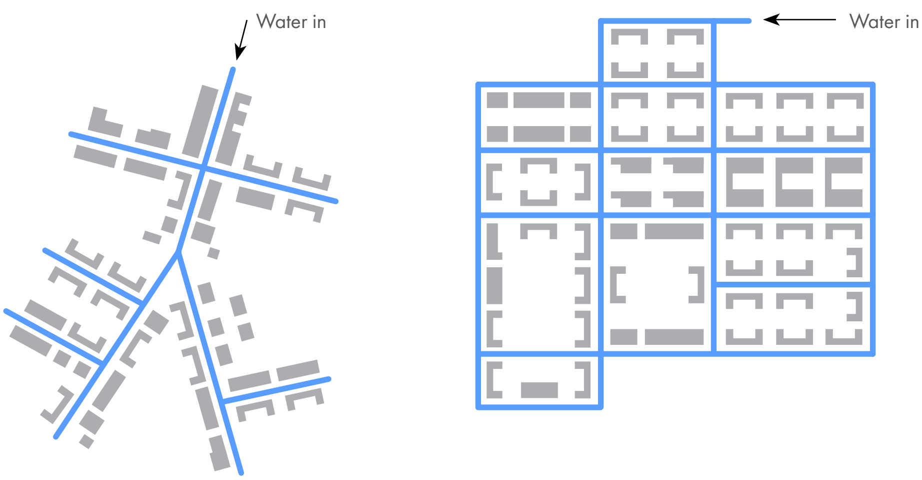


Figure J.4: Branched network (L) and a grid pattern with loops (R)

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

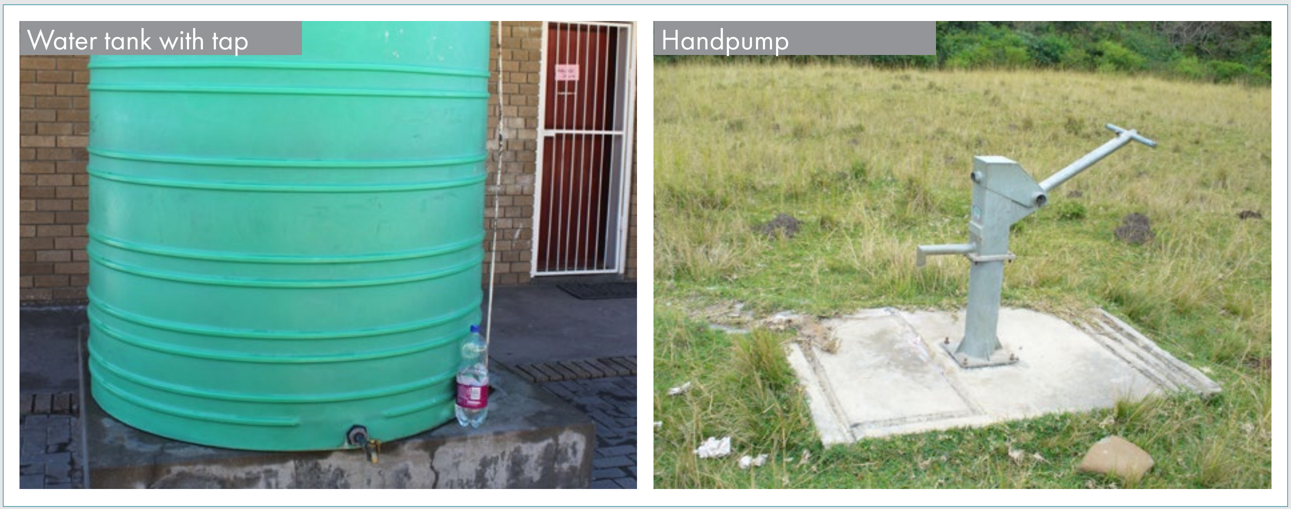


Figure J.5: Examples of public (communal) end-user points of supply

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.

<u>Equation J.1: Area-based method for calculating AADD</u>

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.

<u>Equation J.2: Unit demand method for calculating AADD</u>

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

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 m^2	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 m^2 #2	21	0.65
Industrial	FAR = 0.4	n.a.	kL/100 m^2 #2	13	0.40
Government institutions	FAR = 0.4	n.a.	kL/100 m^2 #2	13	0.40
Warehousing	FAR = 0.4	n.a.	kL/100 m^2 #2	10	0.30
Institutional	FAR = 0.4	n.a.	kL/100 m^2 #2	20	0.60
Municipal services	FAR = 0.4	n.a.	kL/100 m^2 #2	20	0.60
Educational	FAR = 0.4	n.a.	kL/100 m^2 #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/100m^2
	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/100m^2
	Grounds only	12	kL/ha

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

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

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	$<500 m^2$	0 - 20%
	≥ 500 - $\leq 1\ 000 m^2$	0 - 30%
	>1000 - $\leq 1\ 600 m^2$	0 - 40%
	$>1\ 500$ - $\leq 2\ 000 m^2$	0 - 50%
	$>2\ 000 m^2$	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.

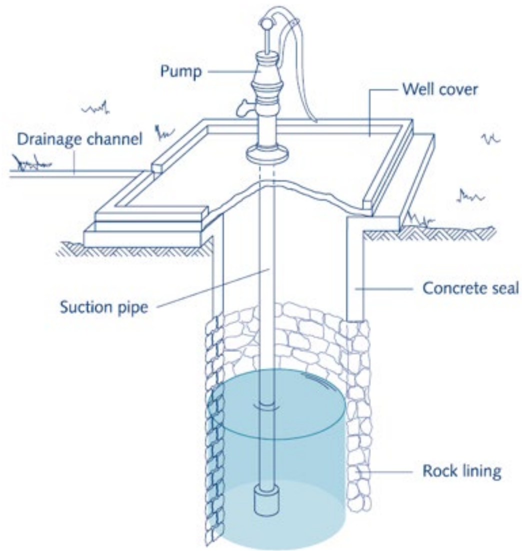


Figure J.9: Hand-dug well

Acknowledgement: Smet and Van Wijk[32]

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).

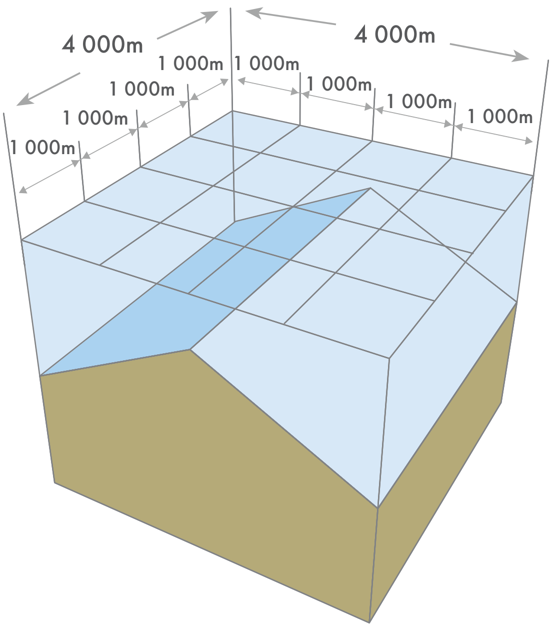
The typical runoff coefficient for different roof surfaces are shown in Table J.11. Runoff coefficients are variable and dependent on the antecedent moisture conditions and the depth of rainfall.

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.

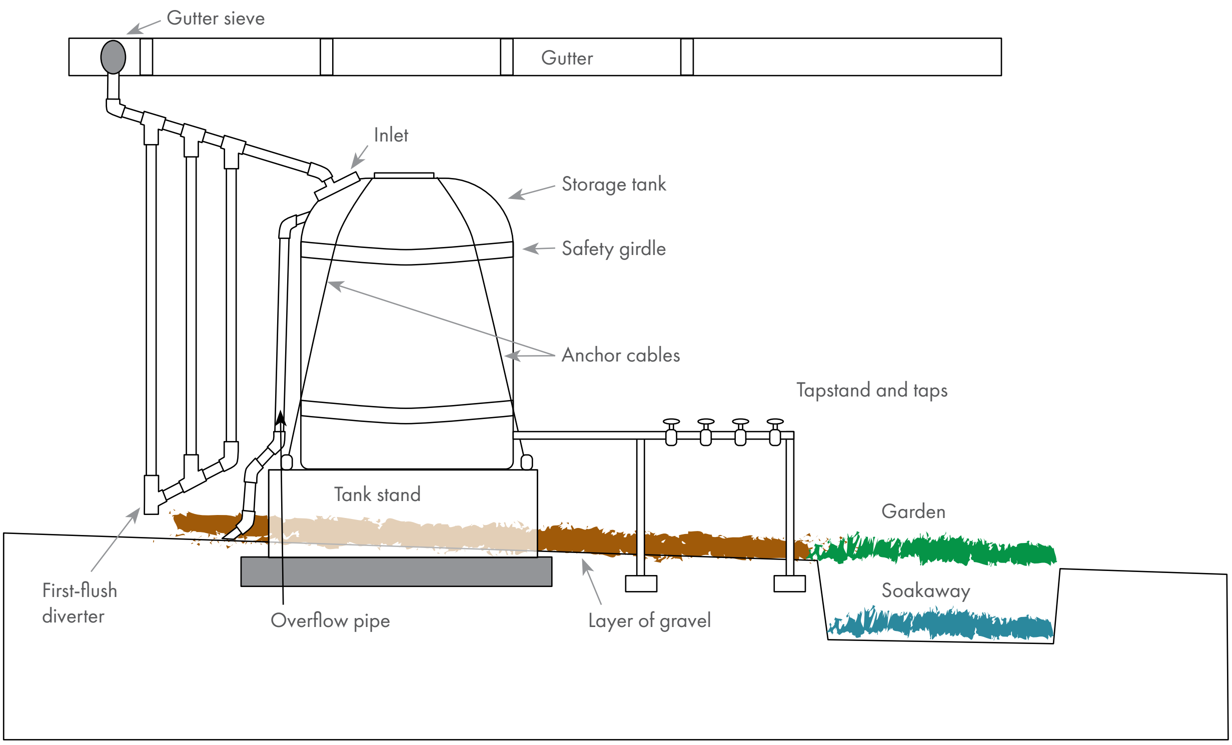


Figure J.12: Components of a rainwater harvesting system

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.

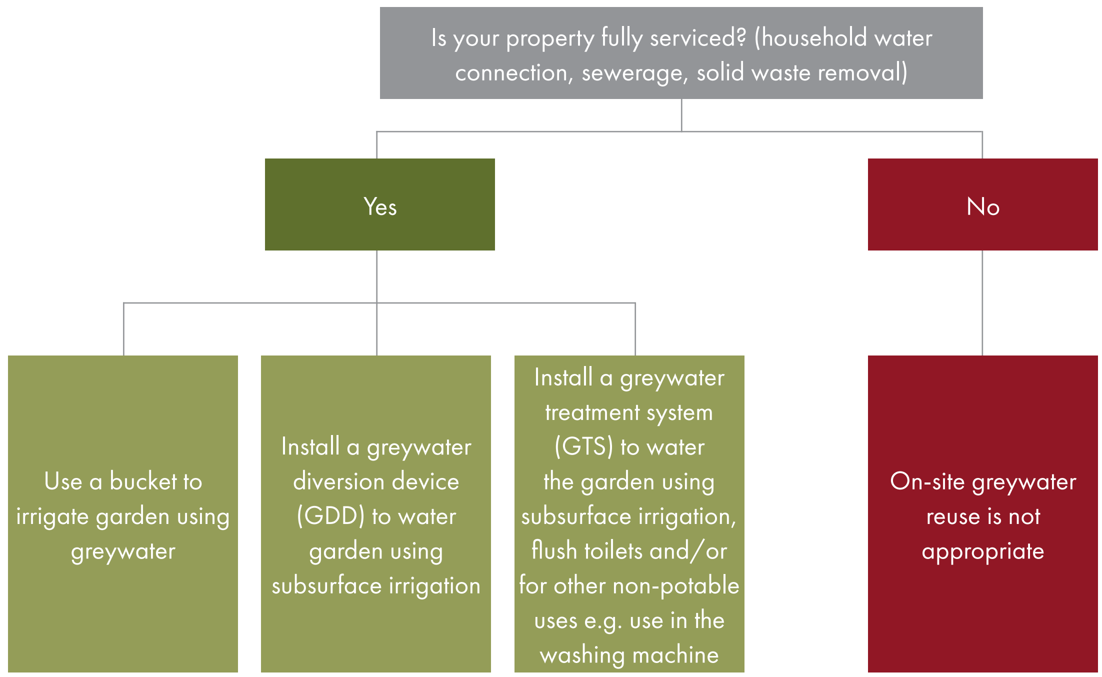


Figure J.14: Permissibility of greywater use[40]

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.

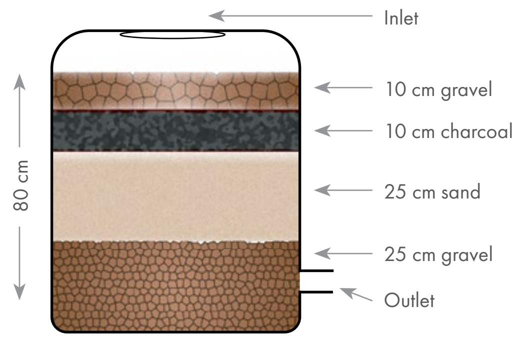


Figure J.15: A sand filter (L) and an example of packaged water treatment (R)

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

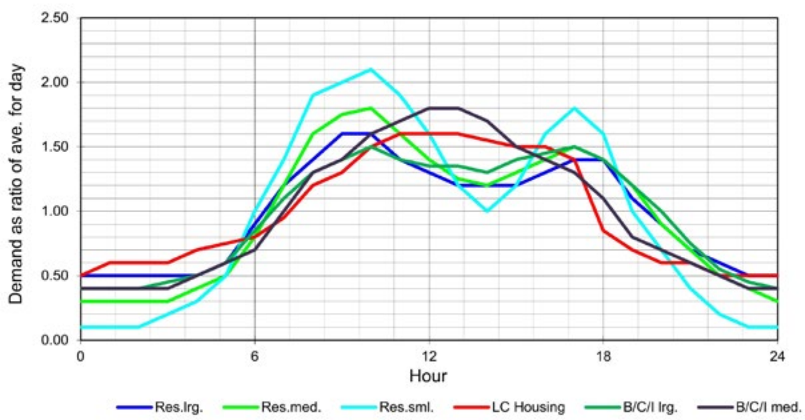


Figure J.16: Typical 24-hour demand pattern

(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.

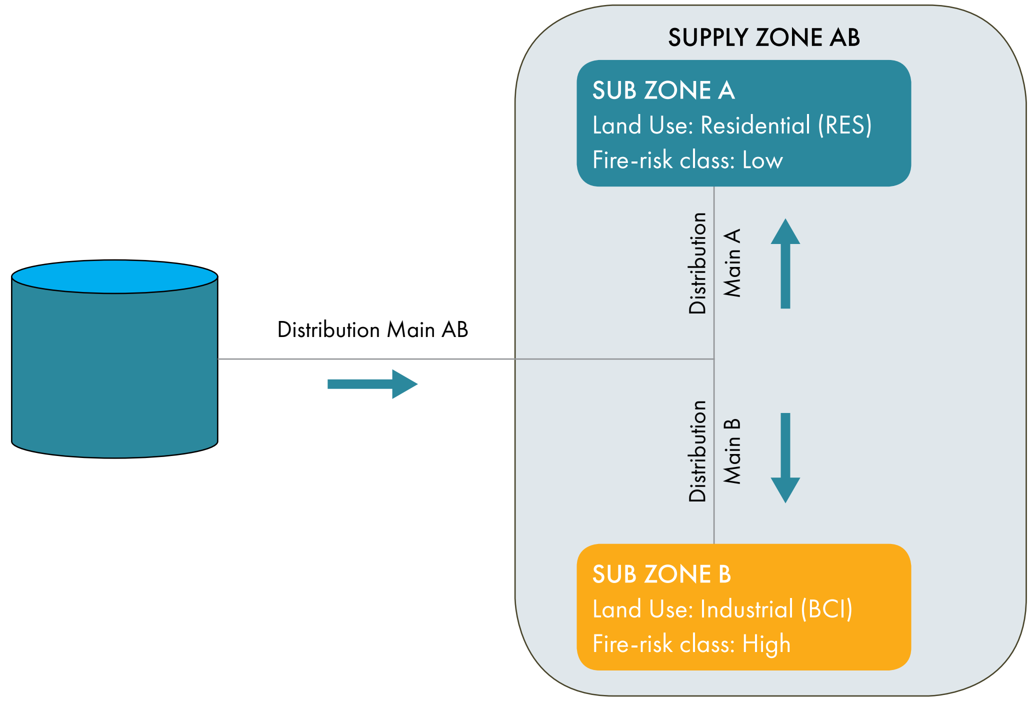


Figure J.17 Design of distribution mains with differing fire-risk categories

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.

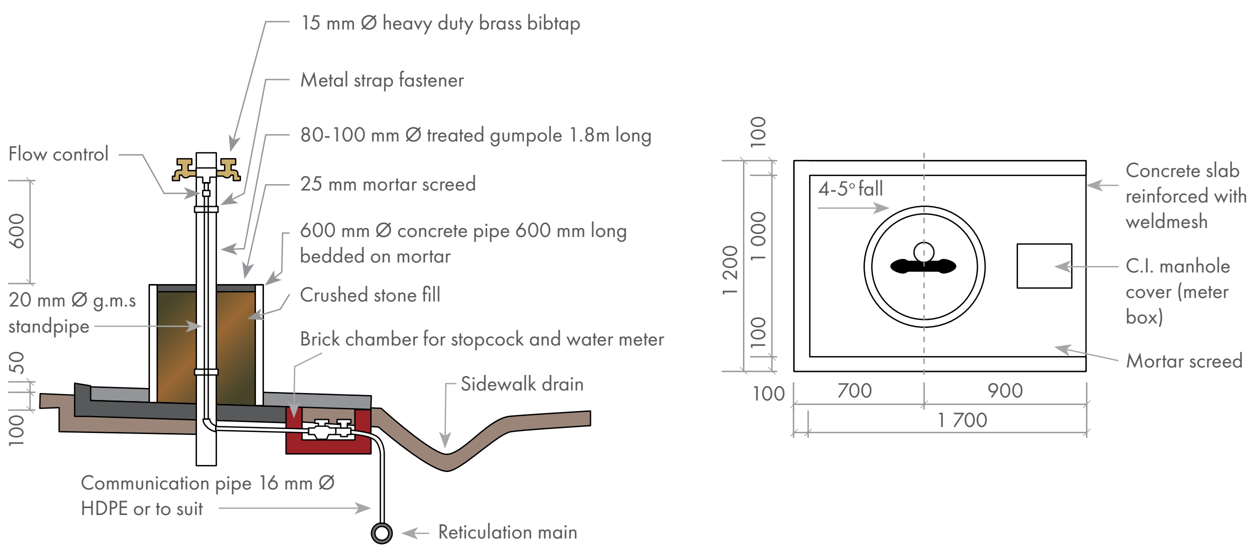


Figure J.18: Typical standpipe detail

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).

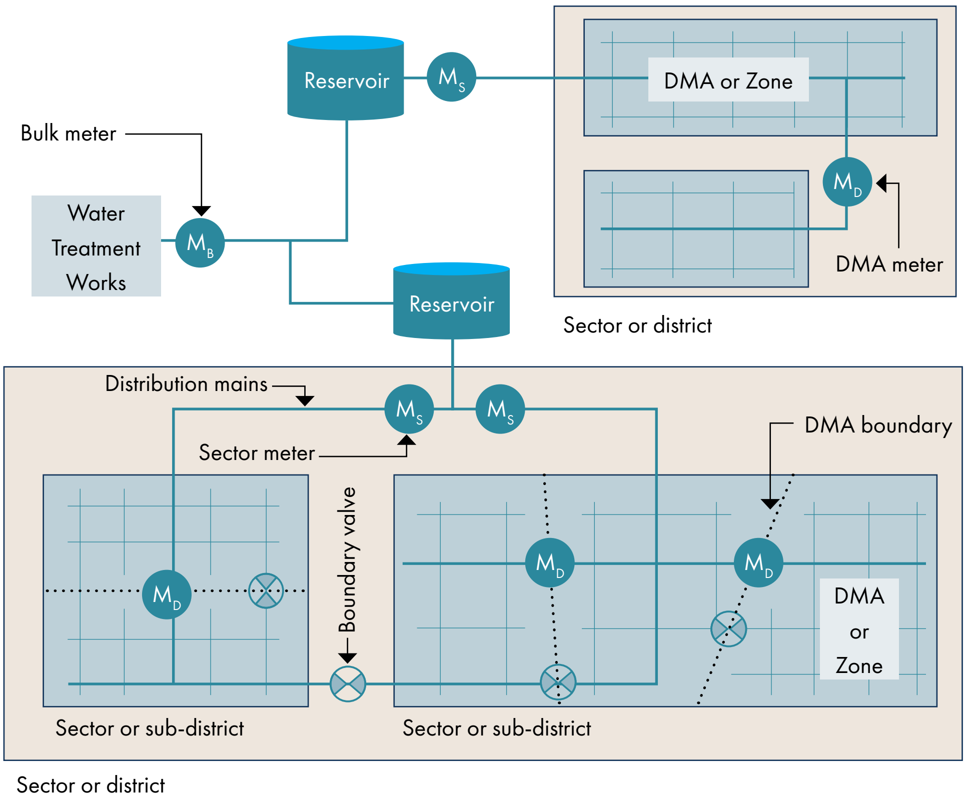


Figure J.19: Sectorising of a water supply zone

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/

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[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/.

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[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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Section K
Sanitation

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 K
Sanitation

The Neighbourhood Planning and Design Guide

Table of contents

K.1 Outline of this section

K.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 sanitation (including wastewater) 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 J** which deals with water supply and **Section L** which deals with stormwater.

K.1.2 Content and structure

This section (Section K) is structured to support effective decision-making related to the provision of sanitation. The decision-making framework is outlined in Figure K.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 sanitation 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 sanitation 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 sanitation that are available for consideration

Design considerations

Guidelines to assist with the design of sanitation systems and infrastructure.

Glossary, acronyms, abbreviations

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

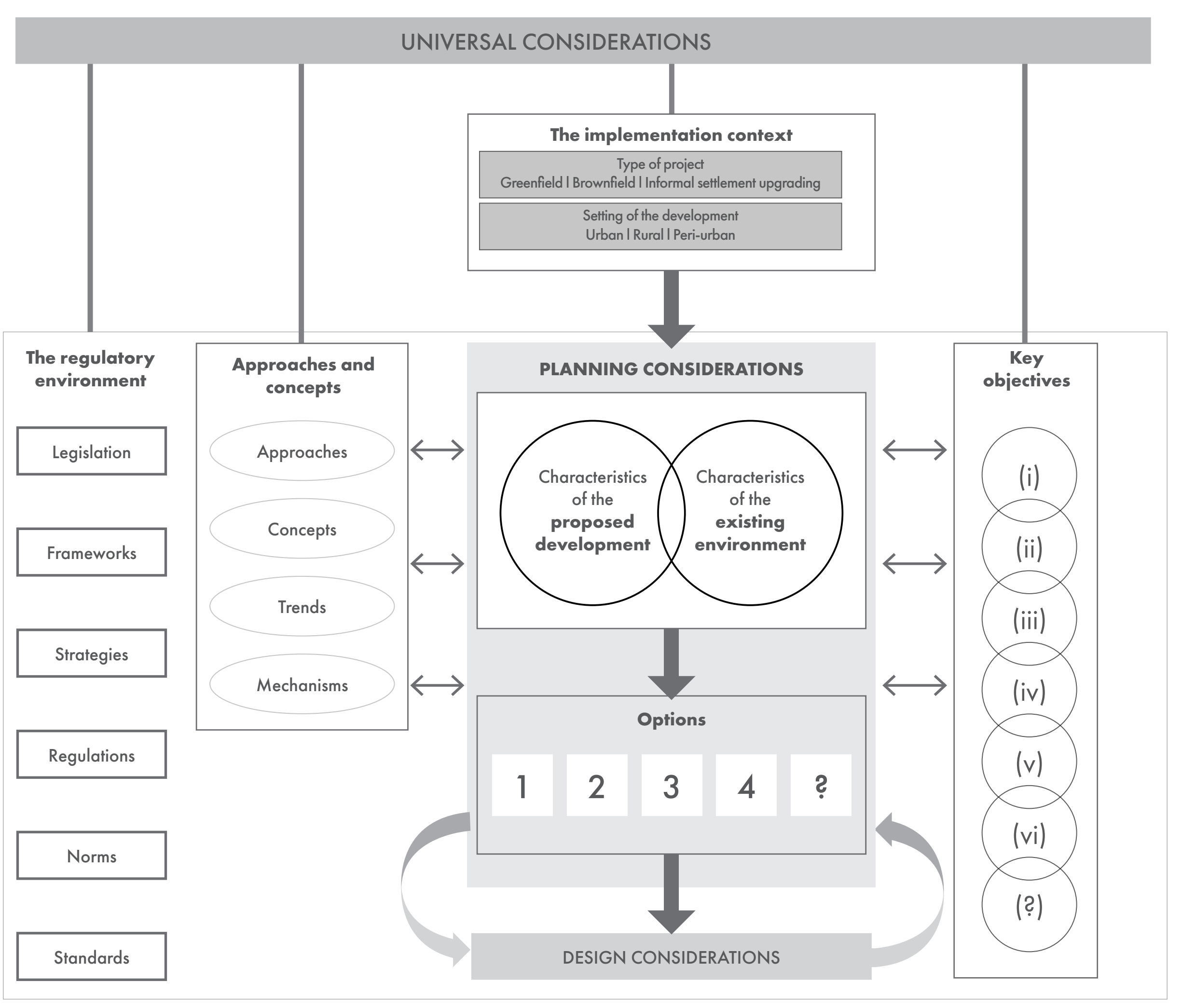


Figure K.1: A framework to assist with planning and design decisions

K.2 Universal considerations

K.2.1 The regulatory environment

A range of legislation, policies and strategies guide the provision of sanitation and wastewater infrastructure and services 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 in a responsible manner, which includes the proper provision of sanitation and wastewater systems.

The National Water Services Act

The legislation that regulates the provision of sanitation and wastewater management in South Africa is mainly the National Water Services Act (NWSA), 1997, supported by the National Water Act, 1998. The NWSA governs the provision of universal access to sanitation and wastewater services to users. Section 3 of the act states that "everyone has a right of access to basic water supply and sanitation". Basic sanitation is defined as "the prescribed minimum standard of services necessary for the safe, hygienic and adequate collection, removal, disposal or purification of human excreta, domestic wastewater and sewage from households, including informal households". Section 3 also states that services authorities must take reasonable measures to realise this right in their Water Services Development Plans, and they must give preference to basic water supply and basic sanitation facilities.

The National Water Act

The National Water Act (NWA), 1998 provides for the regulation of the quality of effluent that may be discharged by a Wastewater Treatment Works (WWTW) into receiving waters. When a WWTW receives more sewage than the works can treat or store temporarily, partially treated or untreated sewage is released directly into receiving waters, which is illegal.

National Sanitation Policy

The National Sanitation Policy of 2016 seeks to address the identified existing sanitation challenges, gaps and burning issues to achieve universal access by 2030. It provides policy positions to address the identified policy gaps and challenges, as well as the country's latest national and international development imperatives. Its focus is to ensure and strengthen integrated sanitation services, institutional arrangements for sanitation services, participation in sanitation services, capacity and resources for sanitation services delivery, financial effectiveness and efficient sanitation services, sustainable sanitation provision in the country, and regulation of sanitation services.

The key objectives for sanitation and wastewater, as set out in the National Sanitation Policy[2], are the following:

- To realise the right of access to basic sanitation – a recognised constitutional responsibility of the national sphere of government, with local government mandated to take reasonable measures to realise this right.
- To give priority to hygiene as well as end-user education in sanitation service provision – hygiene education should be continuous, based on needs, and address all geographic areas in the country. Further, hygiene education should make users aware of their sanitation rights and responsibilities and incorporate water conservation and demand management.
- To give priority to basic sanitation services for vulnerable people and unserved households – in recognition of the special requirements for these individuals and households to gain access to sanitation facilities.
- To provide people-centred and demand-driven sanitation services – sanitation services must recognise sanitation as a right, consider users' expectations and needs in planning and implementation, and devolve decision making and control to the lowest possible levels of accountability. Conversely, the policy recognises that "there is a reciprocal obligation on communities to accept responsibility for their development and governance, with the assistance of the State".
- To reduce pollution through the polluter-pays concept – any reduction of receiving water quality should have a value assigned to it. As such, water quality management shall "include the use of economic incentives and penalties to reduce pollution...", thus placing an obligation on sanitation services to be implemented to reduce pollution.
- To promote the user-pays concept – implementation, regulation and enforcement of the user-pays concept are central to sustainable sanitation service provision. Therefore, the "beneficiaries of the water management system shall contribute to the cost of its establishment and maintenance on an equitable basis".
- To promote the economic value of sanitation – "the public and economic benefit of improved sanitation must be recognised and valued". This should be reflected in how the sanitation by-products are approached and handled, and should recognise the impact of sanitation services on the water scarcity situation in the country.
- To ensure integrated development – sanitation services should be provided in an integrated manner together with other basic services to maximise the public health and economic benefits.
- To ensure equitable regional allocation of development resources – "the limited national resources available to support the provision of basic services should be equitably distributed among regions, taking account of population and level of development".
- To promote the value of sanitation by-products – the recognition of the full value of sanitation by-products, with reinvestment into the system, could foster increased investments and generate efficiency gains.
- To give priority to operation and maintenance – the planning of capital expenditure for sanitation services should take into account the related operation and maintenance costs. Thus, sufficient resources must be allocated for the adequate maintenance of infrastructure and related systems.
- To ensure integrated waste management – the provision of sanitation services should recognise all the various forms of waste emanating from the household. These must be handled (stored, removed and managed) in an integrated and coordinated manner.

National Norms and Standards for Domestic Water and Sanitation Services

The National Norms and Standards for Domestic Water and Sanitation Services of 2017 particularly 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 upheld in 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 receive attention.

The Second National Water Resource Strategy

The water resource protection theme of the Second National Water Resource Strategy (NWRS2) of 2013 emphasises the need to protect freshwater ecosystems that are under threat because of pollution. Reuse of water is becoming more acceptable and feasible because of increasing water shortages, improved purification technology and decreasing treatment costs, taking into consideration public health and safety, as well as water quality management and control.

The National Water and Sanitation Master Plan

The National Water and Sanitation Master Plan (NW&SMP) of 2017 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 to contribute to meeting national development objectives.

The National Framework for Sustainable Development

The National Framework for Sustainable Development (NFSD) of the Department of Environmental Affairs (DEA) emphasises a cyclical and systems approach to 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 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 National Environmental Management: Integrated Coastal Management Act

The National Environmental Management: Integrated Coastal Management Act (ICM Act), 2008 regulates the conservation and sustainable management of South Africa’s coastal environment. Under the ICM Act, anyone wishing to discharge effluent from a land-based source into coastal waters must apply to the DEA for a coastal waters discharge permit.

Water Services Development Plans

Central to providing sanitation and wastewater services to a neighbourhood is the Water Services Development Plan (WSDP) of the relevant Water Services Authority (WSA), which is required in terms of the Water Services Act. The WSDP defines the minimum as well as the desired level of services for communities, which must be adhered to by a Water Services Provider (WSP) in its area of jurisdiction. It describes the current and future arrangements for service provision in an area.

K.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 the provision of sanitation and wastewater infrastructure and services 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.

Poor sanitation systems and inappropriate drainage/treatment of wastewater almost always lead to the pollution of local water sources with pathogens, rendering them unsafe for human use. It is fundamental to sustainable development that local water sources be protected from contamination. It is also vital that due care is taken to minimise the negative downstream effects of wastewater treatment and/or disposal. To achieve the objectives of the 2016 National Sanitation Policy (see Section K.2.1), a sanitation service must meet the following requirements:

- **Sufficient:** The water supply and sanitation facility for each person must be continuous and sufficient for personal and domestic uses. These uses ordinarily include drinking, personal sanitation, washing of clothes, food preparation and personal and household hygiene. According to the World Health Organization (WHO), between 50 and 100 litres of water per person per day is needed to ensure that most basic needs are met and few health concerns arise.
- **Safe:** Everyone is entitled to safe and adequate sanitation. Facilities must be situated where physical security can be safeguarded. This means toilets must be available for use at all times of the day or night, hygienic, constructed to prevent collapse, and wastewater and excreta must be safely disposed of. Services must ensure privacy and water points should be positioned to enable use for personal hygiene, including menstrual hygiene. Ensuring safe sanitation also requires substantial hygiene education and promotion.
- **Acceptable:** All water and sanitation facilities and services must be culturally appropriate and sensitive to gender, life-cycle and privacy requirements. Sanitation should be culturally acceptable and provided in a non-discriminatory manner, including for vulnerable and marginalised groups. This includes addressing public toilet construction issues such as separate female and male toilets to ensure privacy and dignity.
- **Physically accessible:** Everyone has the right to water and sanitation services that are physically accessible within or near their household, workplace, and education or health institutions. Relatively small adjustments to water and sanitation services can ensure that the needs of the disabled, elderly, women and children are not overlooked, thus improving dignity, health and overall quality for all.
- **Affordable:** Water and sanitation facilities and services must be available and affordable for everyone, even the poorest. The costs for water and sanitation services should not exceed 5% of a household's income, meaning services must not affect people's capacity to acquire other essential goods and services, including food, housing, health services and education.[3]

K.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 K.2.2.

K.2.3.1 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 more sustainably to improve water security.[4] 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.[5] 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 K.2).

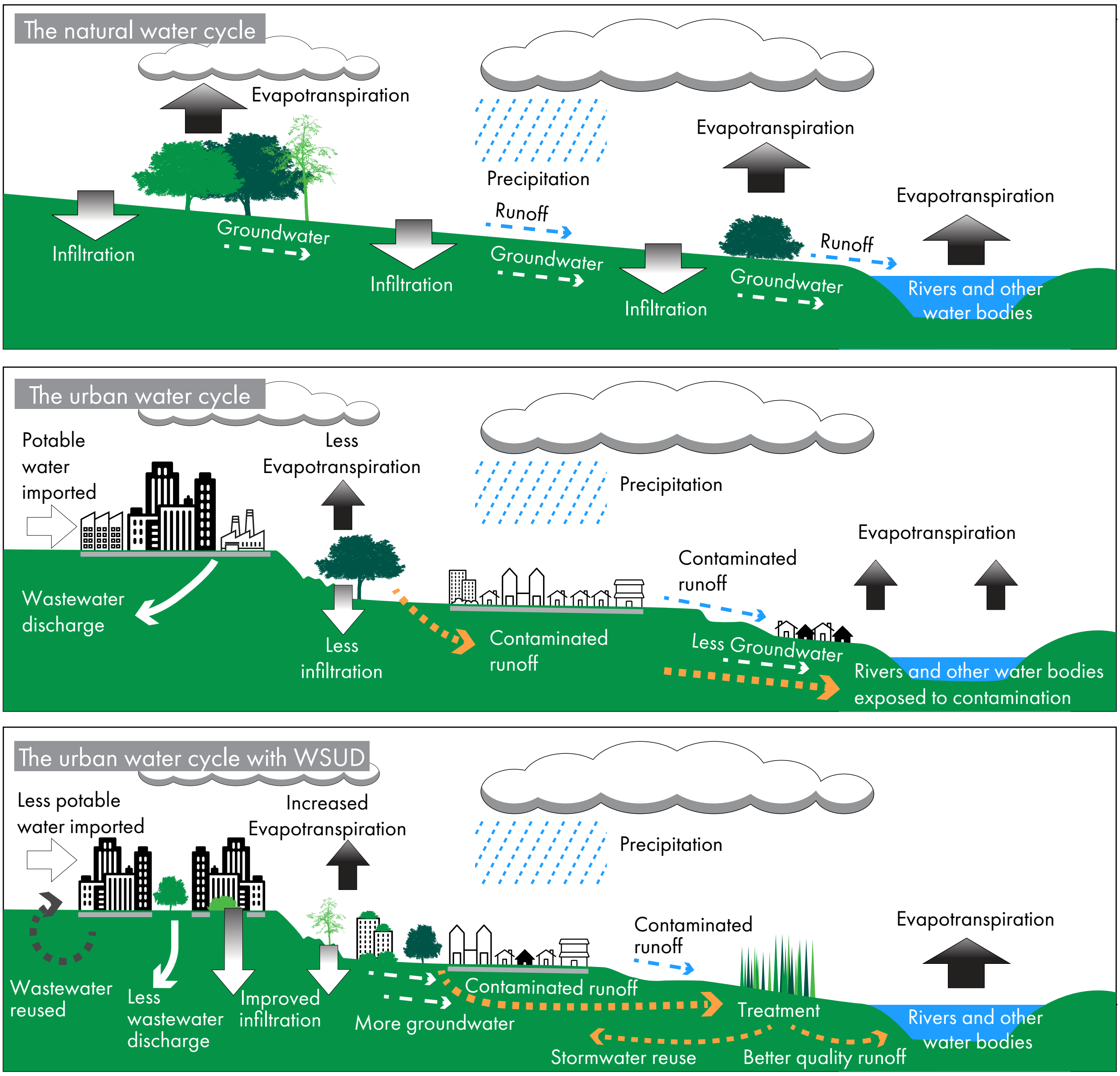


Figure K.2: The water cycle under different conditions

The natural process (water cycle) involves, amongst 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 balance and to create settlements that preserve the natural water cycle. Strategies or interventions that could be implemented include the following:[6]

- **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.[7]
- **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 exploiting 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 J (Water supply), and Section L (Stormwater).

K.2.3.2 Basic sanitation facility and basic sanitation service

A basic sanitation facility is described in the 2016 National Sanitation Policy as "the infrastructure necessary to provide an appropriate sanitation facility which considers natural (water; land; topography) resource constraints, is safe including for children, reliable, private, socially acceptable, maintainable locally, protected from the weather and ventilated, keeps smells to the minimum, is easy to keep clean, minimises the risk of the spread of sanitation-related diseases by facilitating the appropriate control of disease carrying flies and pests, facilitates hand washing and enables safe and appropriate treatment and/or removal of human waste and wastewater in an environmentally sound manner", and a basic sanitation service is "the provision of an appropriate basic sanitation facility which is environmental sustainable, easily accessible to a household, the sustainable operation of the facility, including the safe removal of human waste, greywater and wastewater from the premises where this is appropriate and necessary, and the communication and local monitoring of good sanitation, hygiene and related practices".[8]

K.2.3.3 Sustainable sanitation service

Sustainability of a service is achieved when users want and accept the level of service provided, can pay for it, and the skills are available locally to operate, repair, maintain and upgrade the system. Different service levels come at different costs and they require different activities, capacity and capabilities of a service provider, different systems for operation and maintenance, and different rules for users. These need to be taken into account when planning sanitation services and determining service levels in the diverse areas of the country. A sanitation service is sustainable when it complies with the following requirements:

- Water sources are not polluted
- It provides the services for which it was planned
- It demonstrates a cost-effective use of resources that can be replicated
- It functions properly and continuously, and is used over a prolonged period, according to the designed life cycle of the infrastructure and equipment
- The management of the sanitation service involves the users, is sensitive to gender issues, establishes partnerships with local authorities, and involves the private sector as required
- The operational, maintenance, rehabilitation, replacement and administrative costs are covered at the local level through user tariffs, or through alternative sustainable financial mechanisms
- It can be operated and maintained at the local level with limited, but feasible, external support (e.g. technical assistance, training and monitoring)
- It has no harmful effects on the environment

K.2.3.4 Appropriateness of sanitation and wastewater services

Appropriateness focuses on providing sanitation and wastewater services for people within their contexts – i.e. physical and biological environments; social and economic conditions; governance; funding mechanisms and finances, implementation approaches and methods; technologies and technical issues; water demand for sanitation; and wastewater management. Sanitation and wastewater services that are appropriate consider every element of the context in which the services are provided, especially the natural environment (ecosystem).

Appropriate sanitation technologies minimise the use of natural resources, and minimise the impact on water resources and the environment. They also encourage recycling and reuse, they are sensitive to people with special needs, children, the elderly and women, and they consider the physical, social, cultural, environmental, institutional and economic context.

K.2.3.5 Infrastructure asset management

Asset management is a collection of management practices using assets as the starting point for making operational 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. Sanitation and wastewater systems contain various tangible and intangible assets that need to be managed to ensure that maximum benefit is derived from the use of the assets.

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. Refer to *Water Services Infrastructure Asset Management for Municipal Managers*[9] available from the DWS for more information. On completion, every infrastructure project must have 'as-built' drawings as well as operational and management manuals.

K.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 to plan and design for sanitation and wastewater. Also, refer to **Section D.2.1** (Type of development) and **Section D.2.2** (The setting of the planned development).

Interdependencies exist between sanitation and the other water-related services discussed in **Section J** (Water supply) and **Section L** (Stormwater).

K.2.4.1 The type of development

(i) Greenfield development

Greenfield projects can theoretically accommodate most types of sanitation service delivery. The deciding factor would normally be the availability of water and the most practical, affordable and achievable chance to build neighbourhoods that are land-efficient, fiscally secure and environmentally responsive, and that deliver a better way of life. When planning and designing a sanitation and wastewater system for a neighbourhood as part of a greenfield development project, the following has to be considered:

- Undisturbed portions of the natural environment are often found on greenfield sites. The preservation of natural freshwater ecosystems should be considered when planning and designing sanitation and wastewater systems.
- 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 the planning and design of sanitation and wastewater infrastructure.

(ii) Brownfield development

When planning and designing the sanitation services 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 sanitation and wastewater 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 might have heritage value. Identify heritage elements that need to be protected when constructing sanitation and wastewater infrastructure.

(iii) Informal settlement upgrading

Informal settlement upgrading often involves in-situ development, which implies that existing houses are left in place while the neighbourhood is upgraded. Streets are aligned and widened, drainage is improved, and homes are connected to the water and sanitation grids. When planning and designing sanitation services for an informal settlement upgrading project, the following needs to be considered:

- A Water Services Authority (WSA) 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 grow organically and there may be layouts that seem unconventional. Sanitation and wastewater systems for the upgraded informal settlement have to accommodate these anomalies.
- When planning and designing for sanitation, the higher population density may have an impact on the planning and design of municipal services, as the infrastructure in adjacent neighbourhoods may not have the capacity to cater for these higher densities.

K.2.4.2 The setting of the development

(i) Rural

The rural areas of South Africa comprise a variety of settlement types, including rural villages and towns, dense rural settlements and dispersed settlements. When making decisions regarding sanitation and wastewater systems 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. Sanitation and wastewater planning and design are guided by these decision-makers, rather than by the local municipality's planning and development policies.
- In most instances, communal water points (where water for handwashing is obtained) and on-site sanitation systems are likely to be the most appropriate sanitation service. If waterborne sanitation systems are installed in this context, the Water Services Authority must ensure that the water services provider will be able to maintain and operate the selected sanitation systems.
- Many rural households do not have access to a supply of piped water close to their dwellings. Therefore, household activities often include the collection of water, and in such cases, the provision of sanitation needs to take into account the availability of water for flushing.

(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 sanitation 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.[10] The often high rate of urbanisation should be considered when planning and designing the sanitation 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 sewer treatment.

(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 waterborne sanitation usually offers the most appropriate solution and should be regarded as a basic level of service in terms of the free basic services policy. However, waterborne sanitation should not be regarded as the only option in urban areas.

K.3 Planning considerations

This section deals with the planning of sanitation and wastewater infrastructure. 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 sanitation 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 sanitation and wastewater to be provided as part of a development project.

Decisions regarding sanitation and wastewater 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.

K.3.1 Characteristics of the proposed development

Decisions regarding sanitation and wastewater systems 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.

K.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 sanitation and wastewater systems. The following questions can be asked to gain clarity:

- What is the dominant land use of the proposed development? What supporting land uses will be required? The profile of the development will determine the flow to be accommodated in the sanitation system. The flow from residential developments depends on factors such as the household size, the residential density, the use or non-use of water for conveyance and user preferences and affordability.
- 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.) For instance, tenure may influence decisions on the type of facilities to be provided and residential densities may have an impact on the required capacity of a proposed system.
- What types of sanitation facilities are planned? (See Section K.3.3 for an outline of options that are available.)

K.3.1.2 The residents of the area to be developed

Decisions related to sanitation and wastewater infrastructure need to be guided by information regarding 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 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 provide an indication of the housing types and accompanying services to be provided.
- The range of residents with special needs that would have to be accommodated, e.g. people living with HIV/ Aids and with disabilities, including physical, dexterity and sensory impairment. Sanitation facilities should be accessible to all residents and users.
- Age and gender of residents and those that may make use of sanitation facilities. Gender ratios are, for example, important in providing shared or communal sanitation facilities.
- Income and employment levels, and spending patterns. This would provide an indication of what types of sanitation and wastewater services would be appropriate. For instance, indigent households should at a minimum be provided with basic sanitation facilities and services.
- The cultural profile of the residents. Customs, beliefs, values and practices influence the design of a sanitation system in terms of its acceptability (comfort, privacy, dignity) or fit within a community.
- 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.

Hygiene education and hand washing

Health and hygiene education is defined as all activities aimed at encouraging behaviour that will maintain the conditions that prevent contamination and the spread of sanitation-related diseases, such as the provision of a handwashing facility with water and soap.

Health and hygiene education is a fundamental component of basic sanitation that focuses on changing behavioural practices to prevent the spread of diseases. According to Regulation 2 of the Compulsory National Standards published in terms of the Water Services Act, the minimum standard for basic sanitation services includes "the provision of appropriate education". The provision of simple information to households to strengthen their understanding of the linkages between good sanitation, safe drinking water and comprehensive hygiene is essential.

To enable good hygiene, each toilet should have a handwashing facility at, or close by (within 1 m), and the facility must allow for the washing of hands after using the toilet. This will enable the fulfilment of the requirements of policy, legislation and regulations in the provision of a basic sanitation facility that is easily accessible to a household, the sustainable operation of the facility, the safe removal of human waste and wastewater from the premises (where this is appropriate and necessary), and the communication of good sanitation, hygiene and related practices.[11]

In addition, user education about the proper operation and maintenance of the system is crucial, such as what may or may not be disposed of in the toilet, the amount of water to add if necessary, and what chemicals should or should not be added to the system. The user should also be made aware of what needs to be done if the system fails, or what options are available when the pit or vault fills up with sludge.

K.3.2 Characteristics of the existing environment

Decisions regarding sanitation and wastewater infrastructure need to be guided by an assessment of the context within which the development will be located. Aspects that should be considered are discussed below.

K.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the site could influence the sanitation and wastewater 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 sanitation infrastructure. A steep slope could mean that additional costs will have to be incurred when constructing a sanitation and wastewater system. The topography will also influence the location of infrastructure as costs can be saved by exploiting gravity to assist in the transport of sewage.

(ii) Climate

The micro- and macro-climates of the site will have an impact on various aspects related to sanitation and wastewater infrastructure provision. Issues to consider include the following:

- The temperature, humidity and precipitation in the area influence the effectiveness of the chosen sanitation infrastructure (e.g. whether water is used for conveyance or not).
- The amount of stormwater in an area is rainfall dependent. Sewer systems are usually designed to handle some stormwater ingress and an allowance of 15% to 30% of the dry weather flow is the generally accepted standard. However, stormwater ingress should be prevented as far as possible. See Section K.3.2.2 for additional information on the impact of stormwater ingress on sanitation and wastewater systems.
- The presence (and quantities) of sunlight, wind, waves and geothermal heat in an area can also affect the design of sanitation and wastewater infrastructure when renewable energy is considered as a power source.
- Natural disasters can affect sanitation systems. Is there a risk of seasonal flooding, earthquakes, tremors, and landslides? For assistance with the development of actions to adapt settlements to the impacts of climate change, consult the *Green Book: Adapting South African settlements to climate change*[12].

(iii) 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 sanitation and wastewater infrastructure. The following should be considered:

- What is the soil condition and quality? The soil conditions will dictate the suitability of the proposed containment and disposal methods, especially in the case of on-site disposal.
- 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

position of the groundwater table will dictate the suitability of the containment and disposal methods, especially in the case of on-site disposal.

(iv) Landscape and ecology

The physical features of the landscape could have a substantial impact on the types of sanitation and wastewater systems 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 such systems. 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 proximity of the site to existing water resources. The distance to dams, rivers and streams, or coastal waters is important due to the indication it provides of water availability and the availability of a point of disposal of treated effluent. Also, it provides an indication of possible points of direct contamination.
- 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).[13]
- 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.
- 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.

(v) 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 sanitation and wastewater infrastructure on the site. In particular, the stormwater generated on adjacent sites should be considered, as severe stormwater ingress poses significant risks (see Section K.3.2.2).

K.3.2.2 Available engineering infrastructure

Developments create additional demand for sanitation and wastewater systems and therefore have a potential impact on existing infrastructure. Aspects to consider are discussed below.

(i) Existing sanitation and wastewater infrastructure

Existing sanitation and wastewater infrastructure may be readily accessible. However, the capacity of the existing services needs to be determined as it may not be sufficient to accommodate the proposed development and may require an upgrade to service the proposed development adequately.

(ii) Water supply infrastructure

In many instances the provision of an efficient sanitation and wastewater system is dependent on an efficient water supply system. It is therefore important to determine the availability and capacity of existing water supply systems in the area or to plan the sanitation and wastewater system in tandem with the water supply. It is also important to determine whether there are existing pipelines on the site. Water and sewerage pipes should not be positioned directly adjacent to each other to reduce the risk of cross-contamination when pipe bursts occur. For more guidance on water supply refer to **Section J**.

(iii) Electrical energy

Energy is needed in the operation of wastewater infrastructure systems through processes related to the treatment, transfer, distribution and discharge of wastewater. The availability of electrical energy is critical for the operation of sanitation and wastewater infrastructure. In addition, the efficient use and management of energy is important when planning sanitation and wastewater infrastructure. Refer to the Water Research Commission's (WRC) *Energy Efficiency in the South African Water Industry: A Compendium of Best Practices and Case Studies*[14] for information on energy efficiency best practice, tools and technologies to be considered by the sanitation and wastewater industry. Where opportunities exist, wastewater treatment facilities should be encouraged to implement biogas energy production projects. Refer to **Section N** for guidance on electrical energy.

(iv) Stormwater management

The availability of sufficient stormwater management infrastructure is critical in the planning of sanitation and wastewater systems as there is a need to reduce the quantity of stormwater ingress in sewer systems. Stormwater ingress is defined as the infiltration of stormwater and groundwater into urban sewage systems. The *National Building Regulations* (SANS 10400)[15] state in Regulation P3(2): "No person shall cause or permit stormwater to enter any drainage installation on any site." The National Water Act also determines that it is illegal for a municipality or wastewater treatment works to discharge untreated or partially treated sewage into receiving waters. Stormwater and surface inflows can account for dramatic peak flows in the sewer system (up to three times the average dry weather flow). For guidance on the planning and design of stormwater management infrastructure, refer to **Section L**. Sewer systems are usually designed to handle some stormwater ingress and an allowance of 15% to 30% of the dry weather flow is the generally accepted standard, but stormwater ingress should be avoided because of the following:

- The risk of overflows of untreated sewage increases with stormwater ingress, which has public health and environmental health implications. Storage of untreated sewage in stormwater retention dams also creates human and environmental health risks.
- There are cost-related implications to severe stormwater ingress. For instance the more effluent a works receives, the higher the treatment costs. Also, bulk sewer lines have to be upsized, which is capital intensive. Capital expansion programmes may need to be considered at wastewater treatment works if they are to deal effectively with storm surges, as the works needs the capacity to absorb peak flow (and not average flows) if spillages are to be completely avoided.
- Extraneous flow can reduce the originally designed capacity of a sewage collection system and negatively affect the operation of the entire waterborne sanitation system, including the wastewater treatment component. The effluent during extraneous flows may not comply with the required standards, due to the higher pollution loads and the partially treated water at the treatment works.

K.3.2.3 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?

The economic feasibility of sanitation systems

The selection of an appropriate sanitation system is, among others, influenced by the economic feasibility of the system. Issues that need to be considered include the availability of funding; the tariff structure applicable in the municipality; users' willingness to pay for the service; users' ability to pay for the service; the cost of construction; the availability of construction materials, parts, etc.; operation and maintenance costs; and rehabilitation or redundancy costs.

When the costs of different systems are compared, all relevant factors should be taken into account. The following examples of costs should not be ignored:

- A pit toilet may require relocation on the site, or emptying every 4 to 10 years, depending on its capacity.
- Sludge from septic tanks and other on-site sanitation systems may require treatment before disposal.
- Training may be required for operators and maintenance staff.
- The community may have to be trained in the use of the system for it to operate effectively.
- Regional installations such as treatment works may be required.
- Special vehicles and equipment may be required for operation or maintenance.

K.3.3 Sanitation and wastewater options

Providing appropriate sanitation and wastewater services to a settlement as a whole requires a mixture of systems that are appropriate for different parts of the settlement and that can be implemented at different scales. The same model of service delivery will not necessarily be appropriate for all areas.

Sanitation systems typically consist of a user interface (the type of toilet), the conveyance/transport of sewage and wastewater, the treatment of sewage and wastewater, and the end use or disposal of treated effluent and sludge (biosolids). This section firstly presents different sanitation facility options that are available for neighbourhood development projects. It then briefly discusses different sewage treatment options, and options for the management of treated effluent, sludge (biosolids) and greywater.

K.3.3.1 Sanitation facilities

A range of technology options is available, from dry on-site sanitation to centralised waterborne sanitation and wastewater treatment. The selection of the type of sanitation infrastructure or facility should be participative and based on the context, i.e. the preferences and cultural habits of the intended users, the capacity of the services provider (financial and skills), the existing infrastructure, the availability of water (for flushing and water seals), the soil formation (for groundwater and surface water protection) and the capacity of the applicable wastewater treatment methods. Maintenance, repair and eventual replacement of sanitation facilities need to be taken into account when selecting a sanitation system during the planning and design phases. As far as possible, facilities should be hardwearing, robust, durable and easy to maintain (i.e. without the need for specialist skills or equipment).

The protection of the environment from possible pollution by on-site sanitation systems, such as pit toilets and French drains (soakaways), is crucial. Pollution may be caused by infiltration of the leachate from the pits into the groundwater, or by surface runoff through a sanitation system that is positioned in a surface-water drainage way. The preservation of groundwater resources is particularly important, as many South Africans use wells, springs, and boreholes.

Provision of different types of sanitation facilities

Household toilets

Toilets used only by a single household, typically a single family or extended family. Household toilets often serve very large households, or they may be regularly used by neighbours.

Shared toilets

Toilets that are shared between a group of households in a single building or on a single plot, e.g. a toilet shared by 20 tenant families each occupying one room in a large building; or a toilet shared by three related families living within a single plot or compound.

Communal toilets

Toilets that are shared by a group of households in a community. In some cases each household will have a key to one of the toilets within a block: this may be one toilet per household, or one toilet for a group of households. Communal toilets should only be selected as an option in situations where individual household toilets are not a sustainable solution. Communal toilets should only be introduced after a detailed investigation of the social and economic context, extensive consultation with the prospective users, and a demonstrated willingness by the users to take ownership of and responsibility for the cleaning and regular maintenance of the toilets. In some cases the service provider may take responsibility for the operation and maintenance elements of a communal toilet.

Public toilets

Toilets that are open to anybody, in public places or residential areas – typically a charge for each use is involved. In most cases the service provider takes responsibility for the operation and maintenance of a public toilet.

The use or non-use of water in the operation of a sanitation system separates the different technology options. As a first step, it is critical to consider the availability of water and the consequences of using water in the sanitation system, thus deciding on using a wet or dry sanitation system option. The next step is to consider whether containment (isolation from human contact), transport, treatment and disposal will take place on site or off site. Table K.1 and Table K.2 show some sanitation system options.

Table K.1: Sanitation technology options not using water

Option	Containment		Transport		Treatment		Disposal	
	On site	Off site	On site	Off site	On site	Off site	On site	Off site
Ventilated improved single- or double-pit toilets (VIP/VIDP)	X		None		None		Either one	
Urine-diverting dry toilet (UDDT)	X		X		X		X	
Ventilated vault toilet	X			X	X (Solids)	X (Liquids)	Either one	
Continuous composting toilet	X		X		X		X	
Biological / electric toilet	X		X		X		Either one	
Anaerobic digester	X		Either one		X		Either one	
Unimproved pit toilet	These options are not allowed as permanent solutions in residential developments							
Bucket toilet								
Chemical toilet								

Table K.2: Sanitation technology options using water

Option	Containment		Transport		Treatment		Disposal	
	On site	Off site	On site	Off site	On site	Off site	On site	Off site
Waterborne sewerage system	None			X		X		X
Low-flush toilet	Either one		Either one		Either one			X
Pour-flush toilet	X		X		X			X
Water recycling toilet	X		X		X		Either one	
Conservancy tank system	X			X		X		X
Anaerobic reactor	X		X		X		Either one	
Shallow sewer	None			X		X		X
Vacuum system	None			X		X		X
Low-flow on-site sanitation system (LOFLO): Aqua privy	X		Either one		Either one		Either one	
Small-scale septic with leach field system	X		X		X		X	
Pour-flush (use of a bucket to throw water for flushing purpose)	X		X		X		Either one	
Biogas digester	X		X		X		Either one	
Solids-free sewer system/ small bore sewer	X		Both		Both		Both	

K.3.3.2 Sewage treatment

The establishment of water treatment plants is the responsibility of the designated Water Services Authorities in terms of the Water Services Act. Depending on the size and purpose of the wastewater treatment plant, local by-laws may also apply. The specific requirements should be confirmed on a case-by-case basis.

The selection of the most appropriate treatment option will be dictated by the General Authorisations in terms of the National Water Act[15] or the specific additional requirements as stipulated by the DWS. Both the quantity of water that needs to be treated and the discharge water quality requirements will play a role in selecting the most appropriate wastewater treatment technology.

Off-site wastewater treatment is considered a specialised subject. It is important to involve specialist consultants where the introduction of a centralised treatment works is considered. When planning off-site sanitation treatment infrastructure, various options are available, of which biofiltration plants (fixed-film systems), activated sludge plants (suspended-growth systems) and pond systems are most frequently used in South Africa

On-site systems that treat sewage at the location mainly involve biochemical treatment processes. The reliability of the selected treatment process and the input required from the owner or operator should be taken into account along with discharge quality requirements when treatment technology options are selected. The General Authorisation in terms of the National Water Act[16] provides discharge requirements for smaller plants. The discharge authorisation will specify the conditions under which the discharge may take place, which will include water quality requirements. Package plants are typically considered for small applications (<100 m^3/day) where pond systems will not produce the required discharge water quality, or where sufficient space is not available. Conventional plants are considered for larger installations. The rules are, however, flexible and dependent on case-specific considerations.

(i) Conventional biofiltration and activated-sludge plants

Conventional plants, whether biofiltration or activated-sludge plants, are selected on the basis of the quantity of water that needs to be treated and the quality of discharge water required. Typically, these installations handle larger flows and can provide a better and more consistent discharge water quality. Various process configurations exist – each with a specific application. The selection of a process is based on detailed analyses of sewage quality and also the specific discharge requirements imposed.

Activated-sludge plants are typically required where a high discharge quality and nutrient removal are required. Given the high level of indirect reuse (intended or otherwise) that is taking place in South African catchments, these plants have been the most common type constructed in recent decades. Biofiltration plants are generally used where the discharge requirements are not as stringent. Biofiltration technology is attractive from a cost and ease-of-use perspective.

Figure K.3: Biofiltration treatment plant (L) and activated-sludge treatment plant (R)

(ii) Pond systems

A pond system is a basic treatment process that makes use of sunlight and algal activity to treat wastewater. Pond systems require a large amount of space in relation to its treatment capacity when compared to biofiltration or activated-sludge plants. Pond systems are often used in rural areas where land is available and relatively affordable, and where wastewater flows are limited. Skilled process controllers are not required on an ongoing basis and, depending on the circumstances, electricity is not required. Stabilisation (or oxidation) ponds are cheaper to build than conventional sewage purification works.

Photo credit (R): WEC Projects

Figure K.4: Example of a pond system (L) and a sewage treatment package plant (R)

Important aspects that should be considered regarding siting and land requirements for pond systems include the cost of the land, the minimum distance between pond systems and the nearest habitation, the direction of the prevailing winds (ponds should, as far as possible, be downwind of town limits), possible groundwater pollution, geotechnical conditions that will influence costs, land that requires irrigation (which is an integral part of the pond system) and the topography of the site (which can influence costs).

Although pond systems are regarded as treatment plants, the effluent does not normally meet acceptable effluent standards for discharge into the catchment area. Pond effluent is therefore generally used for irrigation. A pond system is considered a wastewater treatment works, and its owner should obtain the necessary authorisations from the DWS.

(iii) Package purification plants

A package purification plant is treatment infrastructure that is contained in a small space and consists of mainly prefabricated components. Treatment is accelerated by mechanical and chemical dosing equipment. Technology used is in some instances proprietary to the manufacturer, but it can also be miniaturised versions of conventional activated-sludge or biofiltration plants.

Package plants require the same operational care as large plants and cannot be left to operate 'alone'. Package plants also face unique challenges. These are mainly due to the lack of capacity of the smaller plants to attenuate variations in load or flow, which results in process instability.[17] Approval for the construction and operation of package plants must be obtained from the responsible Water Services Authority for the area in which the package plant is to be provided.

K.3.3.3 End use/ Disposal after treatment

(i) Treated effluent

Treated water can be discharged to natural water courses, can be used for irrigation or, in some cases, can be evaporated. Direct reuse of the water can also be considered.

The discharge of water from large plants (>2ML/d) generally has to be returned to the catchment area.[18] It is necessary to liaise with the DWS when planning plants of this size to obtain the specific requirements of the plant and its discharge, as this will vary from site to site.

Irrigation systems are typically considered for small plants (<500m^3/d) where the treated water quality does not meet the required quality standards for catchment discharge. Irrigation activities are subject to some requirements that are referenced in Section K.3.3.4.

Evaporation of treated water is often the unintended consequence of operating an oxidation pond far below the design capacity in warm climates. This is not ideal as the evaporated water could potentially have been utilised elsewhere. Evaporation is rarely an intended design outcome, as the costs of sizing ponds for evaporation are prohibitive.

By law, treated effluent must be sampled and monitored before reaching the point where it merges with naturally occurring water courses or where it is disposed of in any other way. The disposal approach that is adopted must make sampling possible. Determining the impact of the discharge must also be made possible by allowing access to sample points upstream (not affected by the discharge activity) and downstream of the discharge activity.

(ii) Sludge (biosolids)

Sewage sludge (also known as 'biosolids') refers to the semi-solids left over from municipal wastewater treatment. Treated sludge produced as part of the wastewater management system should be regarded as a resource rather than a waste product. The most valuable utilisation of biosolids is as a fertiliser in agricultural activities. Care should be taken in handling the biosolid mass as it can be a source of contamination. The treatment and conversion of wastewater solids to biosolids is a specialist subject and specialists need to be consulted.

Valuable biosolids can be sourced from on-site as well as off-site wastewater treatment systems. Systems of increasing complexity can be employed at larger facilities under the guidance of subject matter experts to derive biosolids of the highest quality. At on-site systems, it is advantageous to keep the system as simple and as robust as possible, as the responsibility of 'operating' these systems will be at household level. Urine-diversion-based systems are ideal, as this results in a biosolids mass that is easily dried and safely handled. Systems that contain large amounts of water, such as pit toilets and septic tanks, are more complex. In some cases, it may be more sensible to collect the biosolids from these systems to be treated and converted to a useful resource at a centralised treatment or to be disposed of sustainably.

The WRC published guidelines about the beneficial use and safe disposal of biosolids in South Africa. These guidelines consist of the following five documents:

- *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 1: Selection of management options*[19]
- *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 2: Requirements for the agricultural use of wastewater sludge*[20]
- *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 3: Requirements for the on-site and off-site disposal of sludge*[21]
- *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 4: Requirements for the beneficial use of sludge at high loading rates*[22]
- *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 5: Requirements for thermal sludge management practices and commercial products containing sludge*[23]

The guidelines and recommendations are based on a sludge classification system that ranks sludge quality based on its level of sterilisation (biological class), its stability, and its pollutant content (focusing mainly on metal content). Although the WRC guidelines take into account the regulatory requirements associated with sludge use and disposal, these change on an ongoing basis. It is, therefore, necessary to remain abreast of all regulatory changes and to use a sludge treatment specialist to assist in this regard.

K.3.3.4 Greywater

Greywater is defined as untreated household wastewater from all domestic processes other than toilet flushing, i.e. from baths, showers, kitchen, hand wash basins and laundry. Greywater from kitchen sinks, dishwashing machines and activities that could contaminate water with harmful pathogens (including nappy and baby washing) are excluded as a potential resource. Greywater is not only produced on private residential stands, but also at communal washing places, businesses, and taxi stands. Consider the potential use and/or disposal of greywater.

Greywater contains considerably fewer pathogenic micro-organisms and has a lower nitrate content than raw sewage. It also has a more soluble and biodegradable organic content. Greywater has the added advantage of being a handy alternate water source to utilise in place of potable water in a situation where the reduced water quality can be tolerated, such as for toilet flushing or irrigation. Greywater use holds a significant promise as a water use reduction measure. Greywater should however not be considered for potable purposes and must always be used with considerable care. See **Section J.4.2.4** for a discussion on greywater as an alternative water source and see **Section K.4.6** for guidance on the design of greywater management systems.

Greywater as a source for flushing of toilets

Using greywater as a source for flushing toilets is an attractive option to consider in higher-density urban environments. Although this is technically feasible, it can be difficult to justify economically and can be socially unacceptable due to odour and other aesthetic concerns.[24] The aesthetic concerns can be overcome by treating the water before reuse, but this could result in high costs. Careful consideration should be given to practicalities before implementing reuse of greywater for flushing.

K.4 Design considerations

Once an appropriate sanitation and wastewater system has been identified, the infrastructure can be designed. This section provides guidance on the design of different collection, storage/treatment and conveyance infrastructure . It also deals with the calculation of sewage flow and design guidelines for waterborne sanitation systems, wastewater treatment infrastructure, greywater management systems and sludge disposal infrastructure. The section concludes with guidance on materials and the upgrading of various components of existing sanitation systems.

K.4.1 Design of collection, storage/treatment and conveyance infrastructure

The design of a sanitation facility should adhere to the relevant norms and standards as issued and updated by the DWS (refer to **Section K.2.1**). The design aspects of the most commonly used sanitation options are summarised below.

K.4.1.1 Ventilated Improved Pit toilet

Ventilated Improved Pit (VIP) and Ventilated Improved Double Pit (VIDP) toilets do not require water and thus fall within the dry toilet category. The design components are summarised in Table K.3 with typical design layouts illustrated in Figure K.5. For more information regarding the design, construction, operation and maintenance of a VIP toilet, consult *Design, Construction, Operation and Maintenance of Ventilated Improved Pit Toilets in South Africa*[25], available from the WRC.

Table K.3: VIP toilets: Design aspects

Main component	Sub-component	Materials	Design aspects
Substructure	Pit	In highly permeable soil (dry pit) OR In low permeable soil (wet pit)	Can be circular or rectangular (circular more stable)
			Not closer than 2.75 m from boundary fence (for maintenance purposes)
			More than 30 m away and downhill from borehole/well
			Volume of Pit (m^3)= P x N x C +0.5, where: P = number of people (No) N = design life (yr) C = accumulation rate (m^3/person/yr) C (dry pits) = 0.06 m^3/yr C (wet pits) = 0.04 m^3/yr
	Pit lining	Concrete blocks, open-jointed brickwork, cement-stabilised soil blocks, masonry, stone rubble, perforated oil drums, rot-resistant timber, wire mesh-supported geofabrics	Only upper parts in stable soils (minimum 0.5 m from top)
			Partial or full lining, depending on soil stability and groundwater presence
			Top sections of pit walls shall be impervious to the passage of water
			Stormwater and soil ingress to be prevented (lining to extend > 75 mm above ground level)

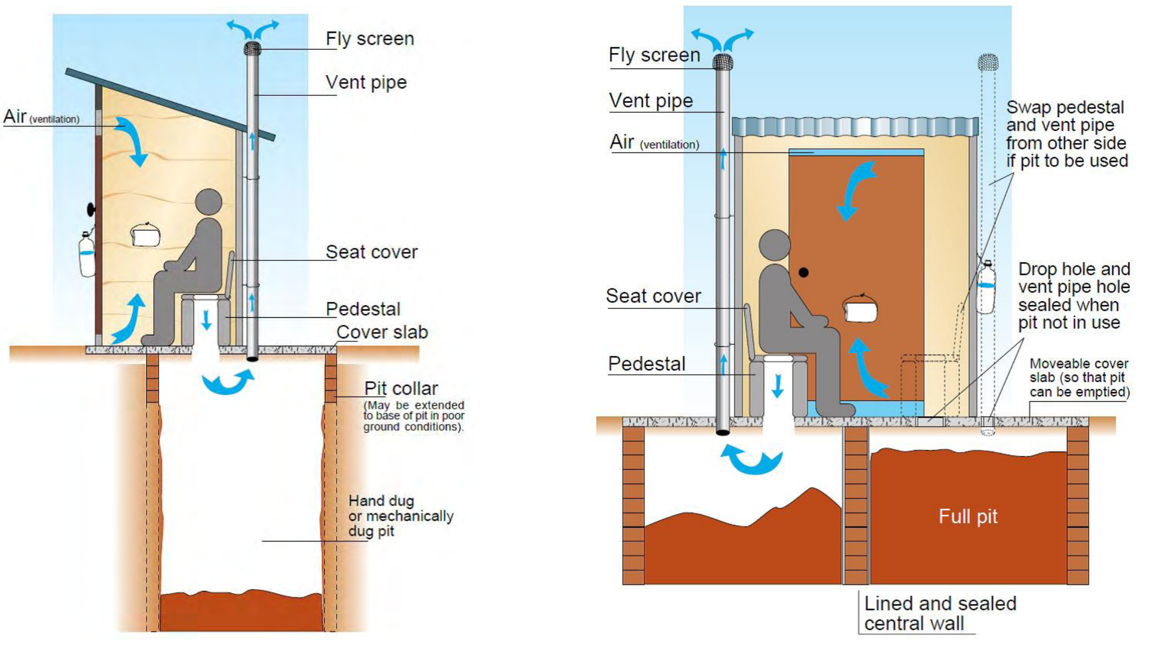
Table K.3: VIP toilets: Design aspects

Main component	Sub-component	Materials	Design aspects
Substructure	Pit collar	Reinforced concrete or bricks/ stone in cement mortar	Must be sufficient to support cover slab
Slab	Cover slab	Reinforced concrete, ferrocement, bricks	Must be properly supported Where a pit is without a collar, 200 mm wider than the pit On good support surface, 50 mm support is adequate
			Reinforced slabs of 75 mm thickness with 6 mm bars at 150 c/c are adequate. 5:1 Sand/cement mix is sufficient. Keep slab damp for 5 days after pour.
			Minimum of 75 mm above ground level
			Maximum of 1 m above ground level
			Holes for squat-hole and vent pipe to be formed
			5% slope towards squat-hole for drainage
Superstructure	General	Materials depend on availability and affordability	Ensure privacy, comfort and shelter
			Waterproof and protect the user from the weather
			Rectangular, circular or spiral shaped (no door required)
			Movability of the structure should be considered when pit cannot be emptied
	Floor	Reinforced concrete	Floor area = 0.8 to 1.5 m^2 (2.35 m^2 for VIDP)
			At least 100 mm above general ground level to prevent flooding when it rains
			Smooth for easy cleaning
	Walls	Brick and blocks preferred Ferrocement not advised	Waterproof
			Smooth for easy cleaning
			Keep out disease-carrying vectors
			Partially darkened structure preferred
			Galvanised wire for vent pipe and roof to be provided
	Door	Wood, steel, composite materials (dependent on availability and affordability)	Face the dwelling, depending on the preference of the users
			Outward opening results in smaller inside area required Inward opening decreases the risk of damage by wind
			Lockable by key on the outside Lockable by a catch on inside

Table K.3: VIP toilets: Design aspects

Main component	Sub-component	Materials	Design aspects
Superstructure	Roof	Reinforced concrete, corrugated iron, clay/fibre cement tiles, thatch, palm leaves, etc. (dependent on availability and affordability)	Waterproof
			Tied to the walls to resist uplift forces
			Slope away from the door
Seat	Pedestal	Brick, mortar, plastic, zinc, fibreglass, ceramic, wood, steel	Beneficiaries to decide
			Maximum width of slab opening of 200 mm
			Seat opening 250 mm to 300 mm
			Seat height 300 to 400 mm
			A toilet seat and lid that can close
			User needs are taken into account – kiddies seat, ramp for wheelchairs, etc.
Ventilation	Ventilation pipe	PVC, uPVC, bricks, blockwork, hessian (steel mesh-supported) etc.	Painted black
			Orientated towards the sun
			Straight to attract flies upwards and maximise airflow
			Preferably on outside of superstructure
			Extending more than 500 mm above the highest point of the roof
			At least 2 m away from anything that can impede airflow (trees, structures, etc.)
	Ventilation openings		Provide without risking privacy
			> 3 times the area of ventilation pipe (0.15 m^2 is adequate)
			Screened
Disease vector control	Fly screen	Corrosion resistant material (glass fibre, aluminium, stainless steel, brass, etc.)	1 mm to 1.5 mm mesh openings
Hand washing	Basin/sink	Brick, mortar, plastic, zinc, fibreglass, ceramic	Running water within 1 m of the toilet
	Water	Potable/safe water	
General considerations			Environmentally sound – protect and conserve water, energy efficient
			Vulnerable groups (children, disabled, aged, women) are ensured safe access
			Located to provide easy access for maintenance/emptying

Table K.3: VIP toilets: Design aspects			
Main component	Sub-component	Materials	Design aspects
General considerations			Downwind of dwelling, not nearer than 10 m and no further than 20 m
			Orientated to ensure privacy and comply with cultural preferences (if applicable)
			Appropriate solid waste disposal to be planned and designed for (including consideration of menstrual health needs)

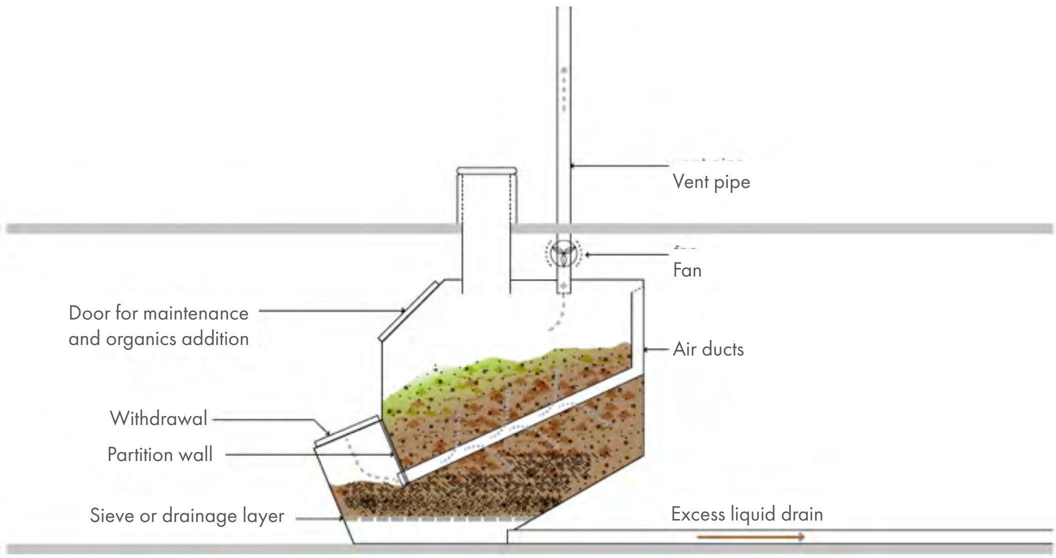


Acknowledgement: DWAF[26]

Figure K.5: Examples of VIP (L) and VIDP (R) toilets

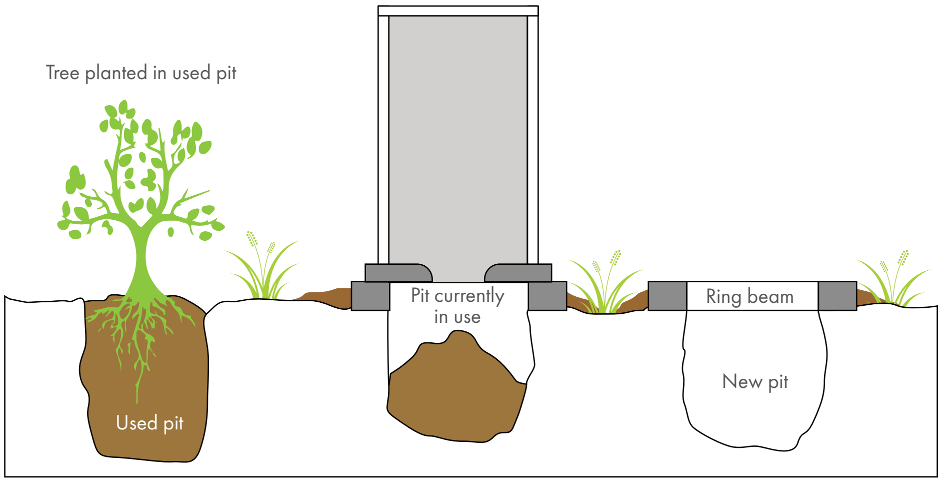
K.4.1.2 Composting toilet

The composting toilet is similar to the VIP toilet and the same design aspects for the superstructure and substructure need to be considered and incorporated. In a composting toilet, excreta fall into a tank/container to which ash or vegetable matter is added. The mixture will decompose to form a good soil conditioner in about four months. Pathogens are killed in the dry alkaline compost, which can be removed for application to the land as a fertiliser. Three types of composting toilets are presented below. In the traditional composting toilet (see Figure K.6), compost is produced continuously. With another type of composting toilet, the contents of the full pit is left to become compost. The pit is then used to plant a tree and a new toilet pit is dug, such as the Arborloo (see Figure K.7). A third composting toilet uses two containers to produce compost in batches, such as the Fossa Alterna (see Figure K.8). More information on composting toilets is available from the World Health Organization.[27]



Acknowledgement: Tilley et al [28]

Figure K.6: Traditional composting toilet



Adapted from Morgan [29]

Figure K.7: The Arborloo

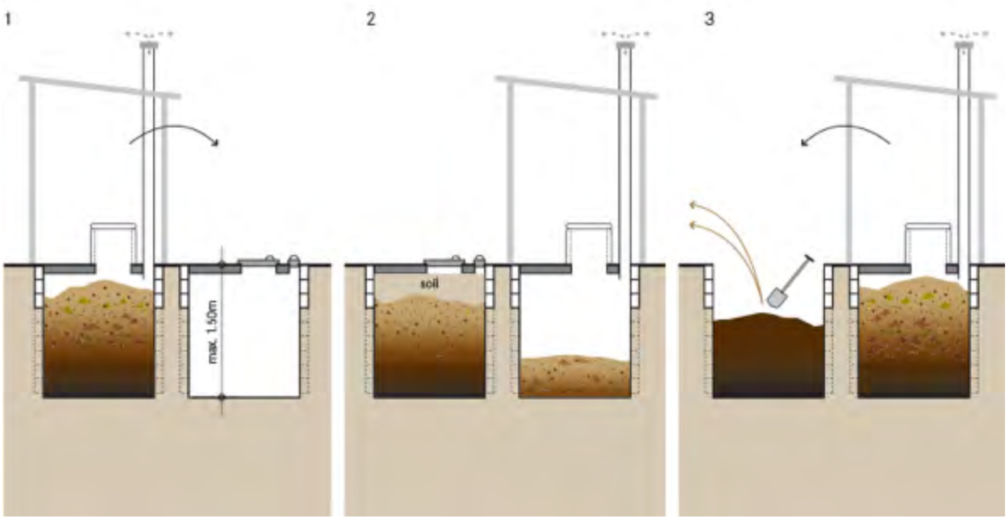


Figure K.8: Fossa Alterna toilet

Acknowledgement: Tilley et al[30]

K.4.1.3 Urine-diverting dry toilet

The urine-diverting dry toilet (UDDT) is a toilet that operates without water and has a divider/receptacle that diverts the urine away from the faeces. The faeces are dried out to be mixed with soil to form a compost. The urine can be collected in a container to be diluted with water and used as a soil conditioner, or it can be diverted to a soakaway. The design aspects for the superstructure of UDDTs are similar to those of the VIP toilet when it is not incorporated as part of the house.

The primary advantage of UDDTs, as compared to conventional dry toilets like VIP toilets, is the conversion of faeces into a dry odourless material. This leads to an odour-free and insect-free toilet that is appreciated by users and allows simple removal and less offensive and safer handling of the faecal material once the storage area has filled up. The functional design elements of a UDDT include source separation of urine and faeces, waterless operation and ventilated vaults or containers for faeces storage and treatment. Comprehensive design details can be obtained from *Guidelines for the design, operation and maintenance of urine-diversion sanitation systems*[31] and from *Technology Review of Urine-diverting dry toilets (UDDTs)*.[32]

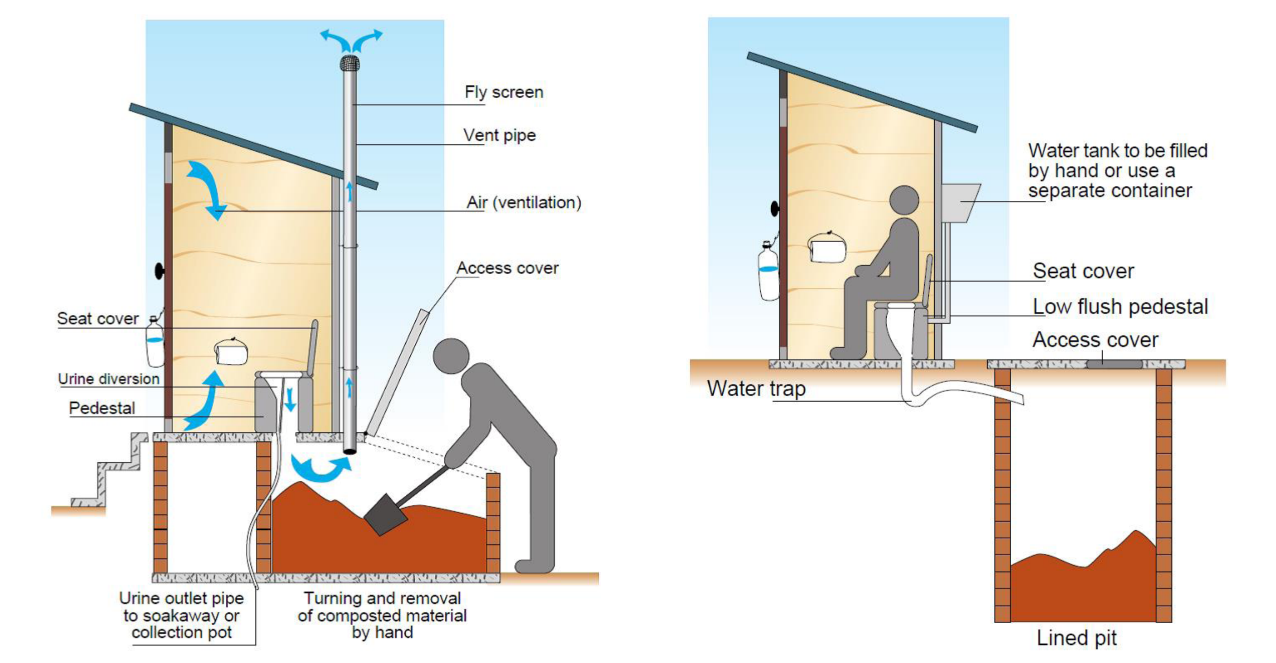


Figure K.9: Examples of a urine-diverting toilet (L) and a pour-flush sanitation system (R)

K.4.1.4 Pour-flush toilet

A pour-flush is a toilet fitted with a trap providing a water seal. It is cleared of faeces by pouring in sufficient quantities of water to wash the solids into the pit and replenish the water seal. The water seal prevents flies, mosquitos and odours reaching the toilet from the pit. The pit may be offset from the toilet by providing a short length of pipe or a covered channel from the pan to the pit. The pan of an offset pour-flush toilet is supported by the ground and the toilet may be within (or attached to) a house. The pour-flush can be retrofitted with a cistern to connect it to a waterborne sanitation system.

The design aspects for the superstructure of a pour-flush toilet are similar to those of the VIP toilet when it is not incorporated as part of the house. More details and information are available from the World Health Organization[34] and from *Developing a low flush latrine for application in public schools*[35], available from the WRC.

K.4.1.5 Aqua privy

An aqua privy is a toilet with the superstructure located directly above (or slightly offset of) a watertight holding tank. The tank is kept topped up with either potable water, rainwater, or greywater. The overflow of the tank can be connected to either a solids-free sewer system, or a soakaway. The design aspects for the superstructure are similar to those of the VIP toilet when it is not incorporated as part of the house. More details and information are available from *A Guide to the Development of On-Site Sanitation.*[36]

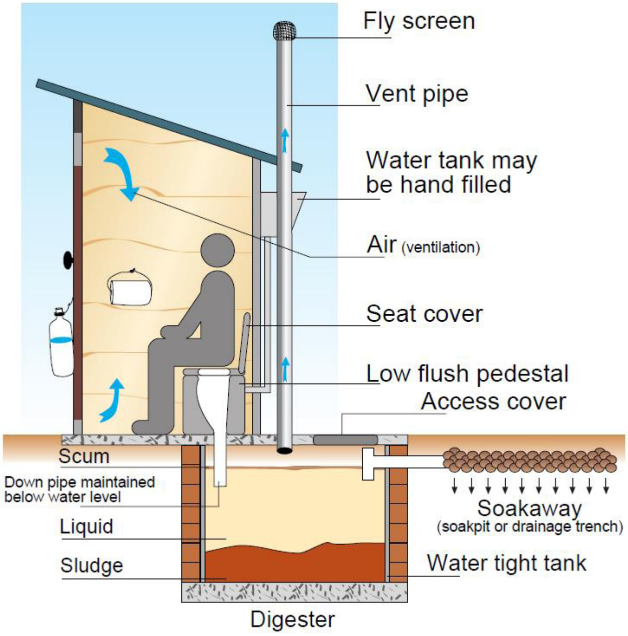


Figure K.10: An example of an aqua privy

Acknowledgement: DWAF[37]

K.4.1.6 Septic leach field system

Septic tanks form part of the sewage disposal system that can be connected to the outlet of any water-flush latrine. An advantage of a septic tank is that the household has all the benefits of the conventional waterborne sanitation with on-site disposal. The disadvantage is that it requires the periodic removal of sludge.

A typical design of a septic tank is shown in Figure K.11. *SANS 10252-2 Water Supply and Drainage for Buildings: Part 2 Drainage installations for buildings provides* national standards on septic tank systems. Relevant information is included in Annexure B of *SANS 10252-2*.[38]

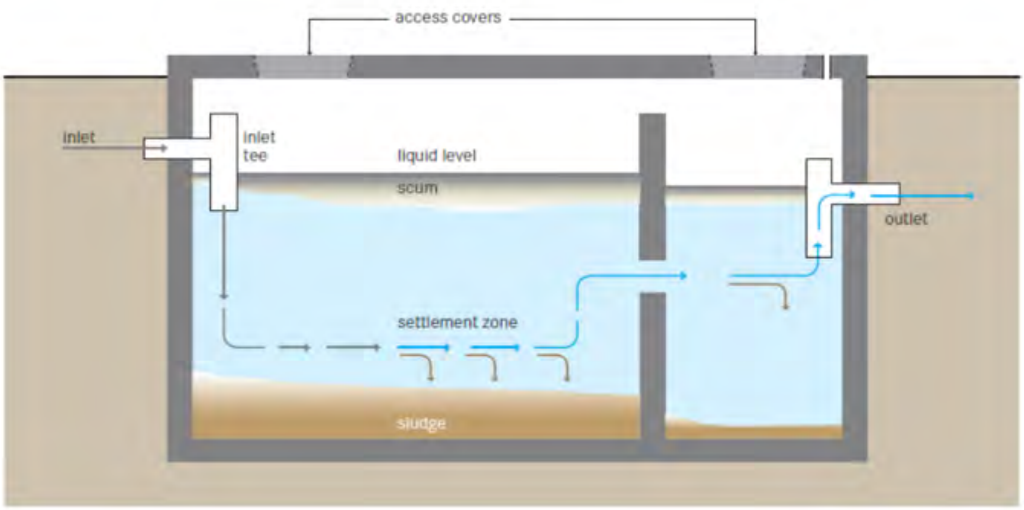
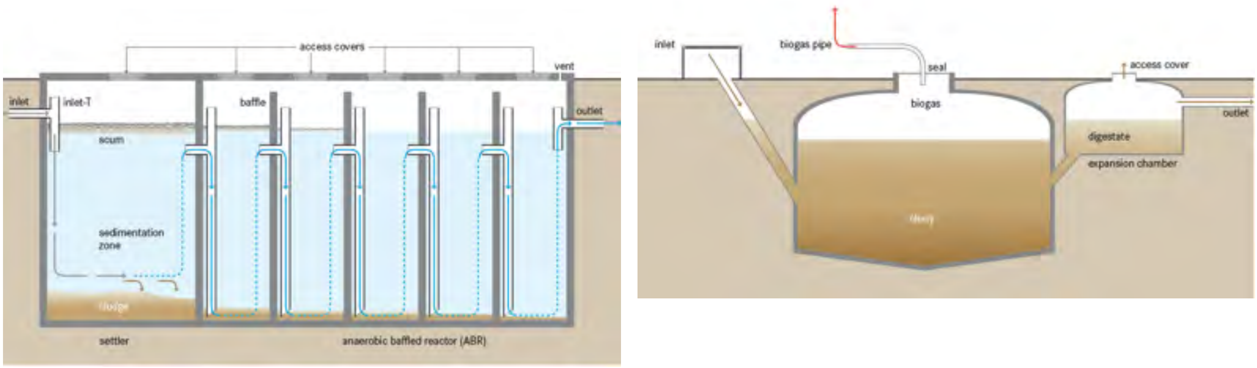


Figure K.11: A two-compartment septic tank with access risers and an effluent screen

Acknowledgement: Tilley et al[39]

K.4.1.7 Anaerobic baffled reactor

An anaerobic baffled reactor is an improved septic tank. The retention time of the liquid in an anaerobic reactor is usually 30 to 50 days, which improves pathogen removal. The system can be connected to a solids-free system that removes the effluent for off-site disposal or to a soakaway, keeping the effluent on site and underground. Figure K.12 illustrates an anaerobic baffled reactor. More information is available from the *Compendium of Sanitation Systems and Technologies.*[40]



Acknowledgement: Tilley et al [41]

Figure K.12: An anaerobic baffled reactor (L) and an anaerobic digester (R)

K.4.1.8 Anaerobic digester/ Biogas reactor

An anaerobic digester is an airtight container in which the waste is dumped and decomposed. Bacteria within the digester tank breaks down the waste and, as it decomposes, gases such as carbon monoxide, methane, hydrogen, and nitrogen, are released. The gas, known as biogas, is captured in a gas holder to be used later to be combusted, or reacted, with oxygen to create an energy source for such processes as heating and vehicle propulsion.

Refer to *SANS 1753 The Construction, installation, commissioning and maintenance of any biogas plan, piping, controls and equipment*[42] for the relevant standards pertaining to anaerobic digesters and biogas. More information is available from *Decentralised Wastewater Treatment Systems (DEWATS) and Sanitation in Developing Countries. A Practical Guide*[43] and the *Compendium of Sanitation Systems and Technologies.*[44]

K.4.1.9 Vacuum sewer system

Vacuum sewer systems make use of a combination of gravity and differential air pressure as the driving force that propels sewage through the sewer network. Vacuum sewer systems consist of three key components: collective chambers, vacuum sewers and the vacuum station. A central vacuum pump station is required to maintain a vacuum (negative pressure) on the collection system (see Figure K.13). The system requires a normally closed vacuum-gravity interface valve at each entry point to seal the lines so that the vacuum can be maintained.[45] These valves, located in valve pits, open when a predetermined amount of wastewater accumulates in collecting sumps. The resulting differential pressure between the atmosphere and vacuum becomes the driving force that propels the wastewater towards the vacuum station. For design details refer to the *Waterborne Sanitation Design Guide*[46] and the City of Cape Town's *Service Guidelines and Standards for the Water and Sanitation Department.*[47]

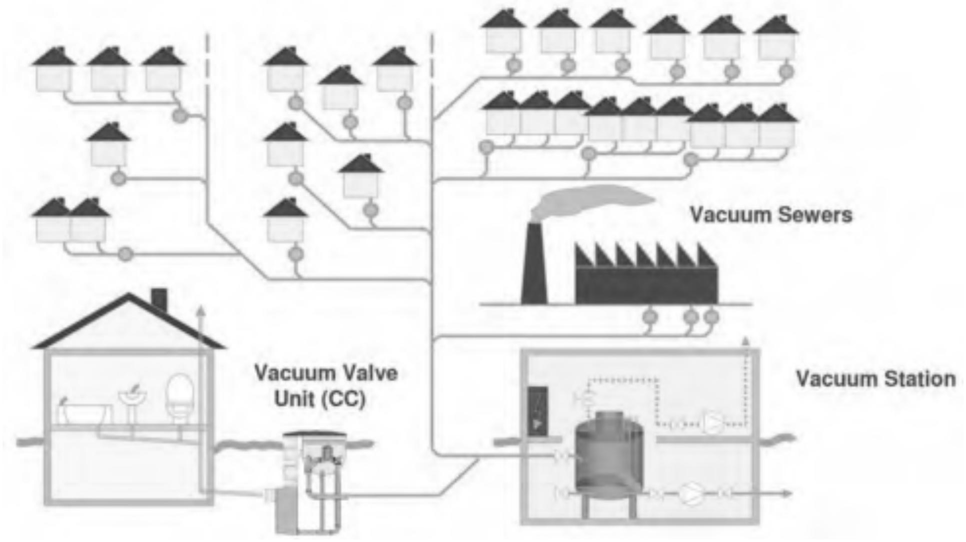


Figure K.13: Vacuum sewer system

Acknowledgement: Bilfinger/Berger[48]

K.4.1.10 Small-bore sewer system

Small-bore systems, or small-diameter-gravity (SDG) sewers, or solids-free sewers (SFS) are also called septic-tank-effluent-gravity (STEG) sewers. These systems convey effluent by gravity from an interceptor tank (or septic tank) to a centralised treatment plant or pump station, from where it is conveyed to another collection system. Another variation on this alternative sewer system is the septic-tank-effluent-pumping (STEP) concept. All these systems utilise smaller-diameter pipes placed in shallow trenches that follow the natural contours of the area, thus reducing the capital cost of the pipe, as well as excavation and construction costs. For design detail, refer to the *Waterborne Sanitation Design Guide*[49] published by the WRC.

Acknowledgement: Tilley et al [50]

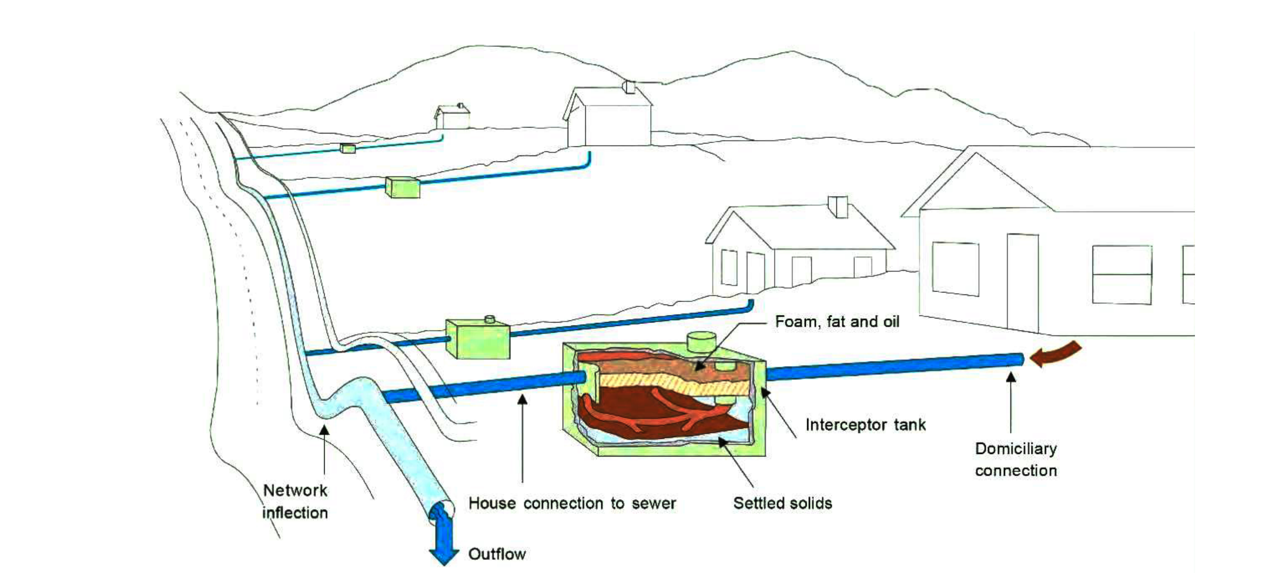


Figure K.14: Small-bore sewer system

K.4.1.11 Simplified/shallow sewer system

A simplified sewer system is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers in order to remove wastewater from the household environment. Many of the conventional sewer design standards, such as minimum diameter, minimum slopes and minimum depths are relaxed in shallow sewer systems, and community-based construction, operation and maintenance are allowed. Expensive manholes are replaced by simple inspection chambers. Each discharge point is connected to an inspection and/or baffle to prevent solids and trash from entering the system. Another key design feature is that the sewers are laid within the property boundaries rather than beneath central roads. Since the sewers are considered more 'communal', they are often referred to as 'condominial sewers'[51]. Simplified sewer systems can be installed in almost all types of settlements and are especially appropriate for dense urban settlements. For design detail, refer to the *Waterborne Sanitation Design Guide*[52] published by the WRC.

K.4.1.12 Waterborne sanitation

Waterborne sanitation consists of a flush toilet connected to reticulation that transports sewage away from the user. Section K.4.2, Section K.4.3 and Section K.4.4 apply to the design of waterborne sewerage reticulation. Certain basic guidelines applicable to non-gravity systems (i.e. pump stations and rising mains) are included, but detailed design criteria for these systems are not included, as they are regarded as bulk services. Except in cases where illustrations are provided, the reader is referred to figures in the relevant sections of *SANS 1200 Standardised Specification for Civil Engineering Construction.*[53]

K.4.2 Sewage flow calculation

Sewers should be designed to avoid possible overflows by making provision for the following flow contributions:

- Regular flow (domestic and/or commercial sewage return flow) plus leakage and base flow (from night flow, leaking cisterns, leaking taps, etc.)
- Infiltration – groundwater seeping through joints/cracks in the pipelines and junctions
- Stormwater ingress – during rainstorms, runoff ingress into the system via illegal connections and inundated junctions

The general procedure for calculating the design flow is illustrated in Figure K.15:

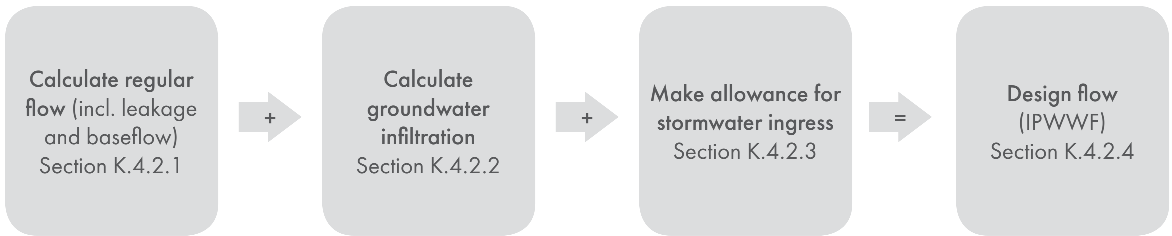


Figure K.15: General procedure for calculating design flow

$$PDDWF \text{ (excl. infiltration) (kL/d)} = \text{Regular flow (kL/d)} + \text{Leakage \& base flow (kL/d)}$$

$$ADDWF \text{ (excl. infiltration) (kL/d)} = \frac{(PDDWF \text{ (excl. infiltration) (kL/d)}}{\text{Peak day factor}}$$

$$\text{Average } PDDWF \text{ (L/s)} = \frac{PDDWF \text{ (kL/d)}}{(24 \text{ h} \times 60 \text{ min} \times 60 \text{ sec})}$$

$$IPDWF \text{ (L/s)} = \text{Peak Factor} \times \text{Average } PDDWF \text{ (L/s)}$$

$$IPWWF \text{ or Design Flow (L/s)} = \frac{IPDWF \text{ (L/s)}}{(1 - \text{Required spare capacity})}$$

Where:

PDDWF = Peak Daily Dry Weather Flow (total wastewater flow representing the peak day in a week)
ADDWF = Average Daily Dry Weather Flow (total average wastewater flow)
IPDWF = Instantaneous Peak Dry Weather Flow
IPWWF = Instantaneous Peak Wet Weather Flow (design flow)

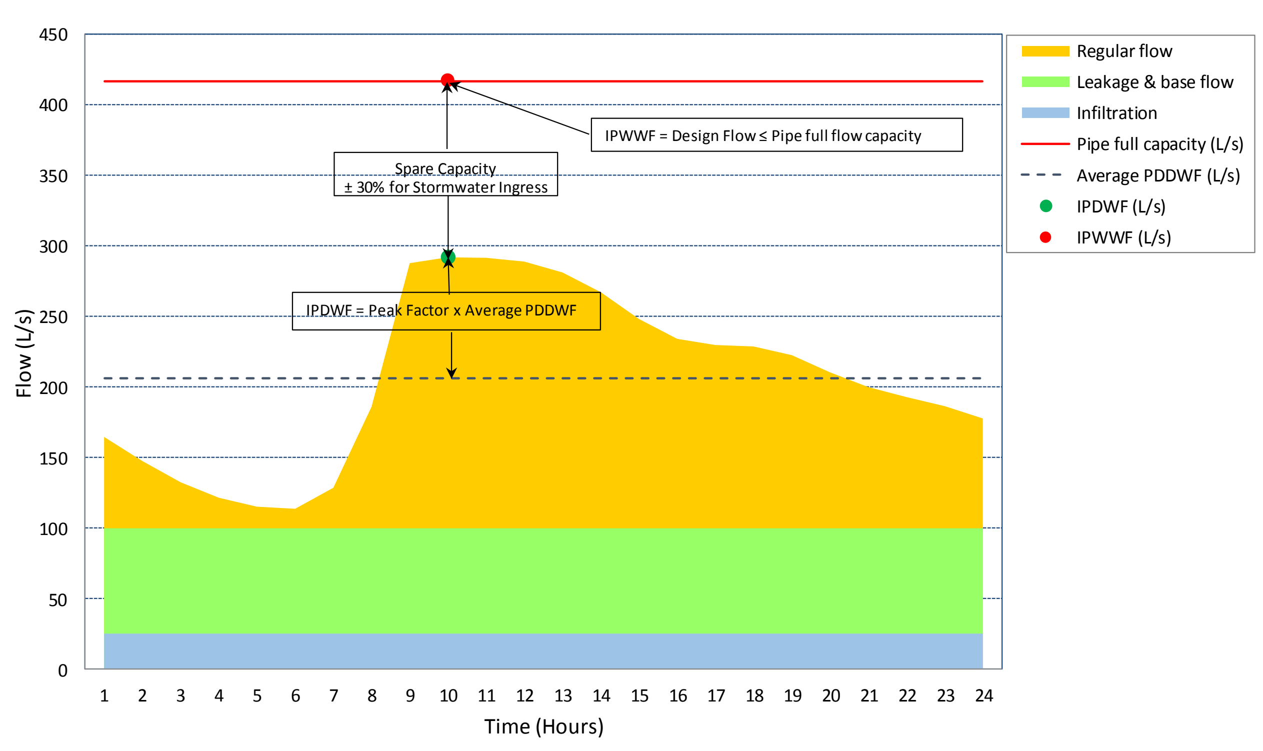


Figure K.16: Sewer outflow hydrograph

K.4.2.1 Regular flow

Three methods can be used to calculate the regular flow (including leakage and base flow):

- Unit hydrograph method – if the Average Annual Daily Demand (AADD) is unknown, but land use and Peak Daily Dry Weather Flow (PDDWF) are known
- AADD method – if the AADD, percentage AADD sewer contribution, and land use are known
- Sewer flow and peak factor method - if the PDDWF and land use are known (traditional method)

These three methods are discussed in detail and examples are provided.

(i) Unit hydrograph method

This method uses contributor unit hydrographs for different land use categories to calculate the expected theoretical peak flows and sewage volumes. It can be used when the AADD is not known for the specific land use(s). The inflow at a time (t) is calculated using the following formula:

$$HQ_t \text{ (L/min/unit)} = UH_t \times \text{Peak} + \text{Leak}$$

$$\text{Unit } PDDWF \text{ (kL/d/unit)} = \tfrac{1}{24} \textstyle\sum_{t=1}^{24} HQ_t \times (24 \text{ h} \times 60 \text{ min}) \div 1\,000\ L$$

$$TQ_t \text{ (L/s)} = HQ_t \times \left(\frac{UQ \text{ (kL/d/unit)} \times 1\,000 \text{ L} \div (24 \text{ h} \times 60 \text{ min})}{\frac{1}{24} \sum_{t=1}^{24} HQ_t} \right) \times EE \times 60 \text{ sec}$$

Where:

UH_t = Unit hydrograph value for land use type at a specific time step (from Table K.5)
Peak = Hydrograph peak flow for land use type (from Table K.5) in L/min
Leak = Hydrograph leakage and base flow for land use type (from Table K.5) in L/min
UQ = Unit PDDWF for land use type (from Table K.4, second last column) in kL/d/unit
EE = Number of units or land parcels per land use type
HQ_t = Calculated unit flow at a specific time step for land use type in L/min/unit
TQ_t = Calculated flow at a specific time step for land use type in L/s

From the unit hydrograph method the following design values can be calculated:

- **IPDWF (excl. infiltration)** (Instantaneous Peak Dry Weather Flow) calculated as the maximum value of TQ_t for each land use for the peak day as follows:

  $$IPDWF \text{ (excl. infiltration) (L/s)} = \max (TQ_{t1..24})$$

- **PDDWF (excl. infiltration)** (Peak Daily Dry Weather Flow) calculated as the average value of TQ_t for each land use for the peak day, or the sum of the number of units multiplied with the unit PDDWF for each land use:

  $$PDDWF \text{ (excl. infiltration) (kL/d)} = \text{Number of units } [EE] \times \text{Unit } PDDWF\ [UQ] \text{ (kL/d/unit)}$$

- **ADDWF (excl. infiltration)** (Average Daily Dry Weather Flow) can be calculated as the PDDWF (Peak daily dry weather flow for the peak day in the week) divided by the Peak day factor:

$$ADDWF \text{ (excl. infiltration) (kL/d)} = PDDWF \text{ (excl. infiltration) (kL/d)} \div \text{Peak day factor}$$

Table K.4 provides the AADD, PDDWF and recommended UH-type for various land use types and densities. The recommended hourly ordinates of each UH-type are tabulated in Table K.5 and illustrated in Figure K.16 for a 24-hour period.

Worked example S1 – Unit hydrograph method

This worked example describes the Unit Hydrograph Method in determining the flow for 50 medium-density residential (UH2) units and 30 business/commercial property (UH7) units. The input data is obtained from Table K.4 and Table K.5 and the calculated values are shown in Table K.6.

Calculate each hourly interval for the 'medium-density residential' land use type excluding infiltration:

Example: Calculation for hour 1 of 24-hour time step:

Unit flow* (HQ_t) for hour 1 = UH_t x Peak + Leak
= 0.15 x 0.64 L/min/unit + 0.19 L/min/unit
= 0.286 L/min/unit

Calculated unit *PDDWF** = Average of HQ_t for the 24h period L/min/unit x (24 h x 60 min) ÷ 1 000 L
= 0.542 (L/min/unit) x 24 h x 60 min ÷ 1000 L
= 0.780 kL/d/unit

Flow* (TQ_t) for hour 1 = HQ_t L/min/unit x (*UQ* kL/d/unit ÷ Calculated Unit *PDDWF* kL/d/unit) x *EE* units
= 0.286 L/min/unit x (0.60 kL/d/unit ÷ 0.78 kL/d/unit) x 50 units ÷ 60 sec
= 0.183 L/s

Note: * Flow excludes infiltration

Calculate design flow for 'medium-density residential' land use type excluding infiltration:

*IPDWF** = Maximum of Flow [*TQ*] over the 24h period
= 0.532 L/s

*PDDWF** = Average of flow [*TQ*] over the 24h period x (24h x 60min) ÷ 1 000 L, or
= Number of units [*EE*] x Unit *PDDWF* [*UQ*]
= 50 units x 0.60 kL/d/unit
= 30.0 kL/d

*ADDWF** = *PDDWF* ÷ Peak day factor
= 30.0 kL/d ÷ 1.1 factor
= 27.3 kL/d

Note: * Flow excludes infiltration

Similarly, the flows for the 30 business/commercial (UH7) units can be calculated with the calculated values shown in Table K.6.

Table K.4: Demands and hydrographs for different land use categories

Land use		Density #1 units/ha	Stand size #2 m²	Unit of measure	Water demand (AADD)		Sewer flow (excl. infiltration) (Unit PDDWF) #4		
					kL/ha/d	kL/unit/d #3	% AADD	kL/unit/d #3	Unit Hydro-graph (UH)
Residential stands	High density, small sized	20 to 12	400 to 670	kL/unit	11	0.60 to 0.80	80% to 70%	0.48 to 0.56	UH5
	Medium density, medium sized	12 to 8	670 to 1 000	kL/unit	9	0.80 to 1.00	70% to 60%	0.56 to 0.60	UH3
	Low density, large sized	8 to 5	1 000 to 1 600	kL/unit	8	1.00 to 1.30	60% to 55%	0.60 to 0.72	UH2
	Very low density, extra-large sized	5 to 3	1 600 to 2 670	kL/unit	7	1.30 to 2.00	55% to 40%	0.72 to 0.80	UH1
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	95% to 90%	0.29 to 0.36	UH4
	Medium density, medium sized	20 to 12	400 to 670	kL/unit	7	0.40 to 0.50	90% to 85%	0.36 to 0.43	UH4
	Low density, extra-large sized	12 to 8	670 to 1000	kL/unit	6	0.50 to 0.60	85% to 80%	0.43 to 0.48	UH4
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	n.a.	n.a.	n.a.
	Medium density, medium sized	20 to 12	400 to 670	kL/unit	6	0.30 to 0.35	n.a.	n.a.	n.a.
	Low density, extra-large sized	12 to 8	670 to 1 000	kL/unit	4	0.35 to 0.40	n.a.	n.a.	n.a.
Group/cluster housing	High density	60 to 40	130 to 200	kL/unit	21	0.40 to 0.45	95% to 90%	0.38 to 0.41	UH5
	Medium density	40 to 30	200 to 270	kL/unit	17	0.45 to 0.50	90% to 85%	0.41 to 0.43	UH5
	Low density	30 to 20	270 to 400	kL/unit	14	0.50 to 0.60	85% to 80%	0.43 to 0.48	UH5

Table K.4: Demands and hydrographs for different land use categories

Land use		Density #1 units/ha	Stand size #2 m²	Unit of measure	Water demand (AADD)		Sewer flow (excl. infiltration) (Unit PDDWF) #4		
					kL/ha/d	kL/unit/d #3	% AADD	kL/unit/d #3	Unit Hydrograph (UH)
Flats	Very high density	100 to 80	80 to 100	kL/unit	25	0.25 to 0.30	100% to 98%	0.25 to 0.29	UH6
	High density	80 to 60	100 to 130	kL/unit	23	0.30 to 0.35	98% to 97%	0.29 to 0.34	UH6
	Medium density	60 to 50	130 to 160	kL/unit	21	0.35 to 0.40	97% to 96%	0.34 to 0.38	UH6
	Low density	50 to 40	160 to 200	kL/unit	19	0.40 to 0.45	96% to 95%	0.38 to 0.43	UH6
Agricultural holdings	Including irrigation	< 3	< 2670	kL/unit	12	4.00	40%	1.60	UH1
	Domestic water only	< 3	< 2670	kL/unit	6	2.00	80%	1.60	UH1
Golf estate - excl. golf course water requirements		< 3	< 2670	kL/unit	9	3.00	40%	1.20	UH2
Retirement village		20 to 12	400 to 670	kL/unit	11	0.60 to 0.80	80% to 70%	0.48 to 0.56	UH5
Business/commercial		FAR = 0.4	n.a.	kL/100m² #2	21	0.65	80%	0.52	UH7
Industrial		FAR = 0.4	n.a.	kL/100m² #2	13	0.40	80%	0.32	UH10
Government institutions		FAR = 0.4	n.a.	kL/100m² #2	13	0.40	80%	0.32	UH9
Warehousing		FAR = 0.4	n.a.	kL/100m² #2	10	0.30	80%	0.24	UH11
Institutional		FAR = 0.4	n.a.	kL/100m² #2	20	0.60	80%	0.48	UH9
Municipal services		FAR = 0.4	n.a.	kL/100m² #2	20	0.60	80%	0.48	UH9
Educational		FAR = 0.4	n.a.	kL/100m² #2	20	0.60	65%	0.39	UH8
Cemeteries		n.a.	n.a.	kL/ha	12	n.a.	n.a.	n.a.	n.a.
Parks		n.a.	n.a.	kL/ha	12	n.a.	n.a.	n.a.	n.a.
Sports fields		n.a.	n.a.	kL/ha	12	n.a.	n.a.	n.a.	n.a.

Notes:

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

#2 - Floor area

#3 - Unit type as defined in column 'Unit of measure'

#4 - Regular flow + leakage and base flow

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).

Table K.5: Sewer unit hydrographs

Definition of unit hydrographs															
	Unit Hydrograph (UH) Number														
	UH1	UH2	UH3	UH4	UH5	UH6	UH7	UH8	UH9	UH10	UH11	UH12	UH13	UH14	UH15
	Land use(s) following typical UH pattern														
	Residential Very low density	Residential low density	Residential medium density	Low-income housing	Group/cluster housing	Flats	Business/commercial	Educational	Municipal services/institutional	Industrial	Multipurpose/mixed/other	Agricultural holdings	None (e.g. Public open space)	Unknown	Large users (per kL AADD)
Hr	Dimensionless flow ordinates (relative to hydrograph peak)														
1	0.15	0.17	0.15	0.09	0.15	0.15	0.08	0.08	0.08	0.09	0.08	0.17	0.00	0.09	0.09
2	0.08	0.10	0.09	0.05	0.09	0.09	0.07	0.07	0.07	0.07	0.07	0.10	0.00	0.07	0.07
3	0.06	0.05	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.00	0.06	0.06
4	0.05	0.05	0.05	0.19	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.05	0.05
5	0.05	0.05	0.15	0.49	0.15	0.15	0.06	0.06	0.06	0.06	0.06	0.05	0.00	0.08	0.08
6	0.11	0.44	0.77	0.80	0.77	0.77	0.08	0.08	0.08	0.10	0.08	0.44	0.00	0.25	0.25
7	0.67	1.00	1.00	0.83	1.00	1.00	0.15	0.15	0.15	0.47	0.15	1.00	0.00	0.69	0.69
8	1.00	0.91	0.98	0.93	0.98	0.98	0.34	0.34	0.34	0.68	0.34	0.91	0.00	0.95	0.95
9	0.87	0.94	0.73	1.00	0.73	0.73	0.83	0.83	0.83	0.84	0.83	0.94	0.00	1.00	1.00
10	0.85	0.84	0.66	0.96	0.66	0.66	0.94	0.94	0.94	0.93	0.94	0.84	0.00	0.89	0.89
11	0.82	0.74	0.72	0.89	0.72	0.72	1.00	1.00	1.00	0.94	1.00	0.74	0.00	0.87	0.87
12	0.71	0.59	0.65	0.75	0.65	0.65	0.98	0.98	0.98	0.89	0.98	0.59	0.00	0.83	0.83
13	0.56	0.48	0.61	0.71	0.61	0.61	0.94	0.94	0.94	0.75	0.94	0.48	0.00	0.60	0.60
14	0.50	0.41	0.57	0.74	0.57	0.57	0.89	0.89	0.89	0.81	0.89	0.41	0.00	0.59	0.59
15	0.46	0.40	0.63	0.76	0.63	0.63	0.88	0.88	0.88	0.95	0.88	0.40	0.00	0.53	0.53
16	0.44	0.38	0.66	0.73	0.66	0.66	0.92	0.92	0.92	1.00	0.92	0.38	0.00	0.53	0.53
17	0.41	0.39	0.70	0.70	0.70	0.70	0.84	0.84	0.84	0.89	0.84	0.39	0.00	0.47	0.47
18	0.38	0.48	0.68	0.66	0.68	0.68	0.35	0.35	0.35	0.66	0.35	0.48	0.00	0.37	0.37
19	0.45	0.53	0.72	0.59	0.72	0.72	0.22	0.22	0.22	0.35	0.22	0.53	0.00	0.28	0.28
20	0.49	0.52	0.70	0.51	0.70	0.70	0.15	0.15	0.15	0.22	0.15	0.52	0.00	0.24	0.24
21	0.45	0.51	0.68	0.38	0.68	0.68	0.12	0.12	0.12	0.17	0.12	0.51	0.00	0.20	0.20
22	0.50	0.49	0.57	0.26	0.57	0.57	0.11	0.11	0.11	0.14	0.11	0.49	0.00	0.16	0.16
23	0.40	0.42	0.44	0.18	0.44	0.44	0.10	0.10	0.10	0.12	0.10	0.42	0.00	0.15	0.15
24	0.29	0.28	0.22	0.13	0.22	0.22	0.09	0.09	0.09	0.10	0.09	0.28	0.00	0.13	0.13
	Unit hydrograph parameters (L/min)														
Hydrograph Peak	1.69	1.04	0.64	0.21	0.37	0.24	2.46	4.97	1.93	2.19	1.75	0.59	0.00	0.55	0.50
% of AADD	40%	55%	60%	70%	80%	90%	80%	65%	80%	80%	60%	80%	0%	55%	60%
Leakage & base flow	0.26	0.21	0.19	0.15	0.14	0.21	1.05	2.12	0.83	1.04	0.75	0.15	0.00	0.23	0.21
	Flow hydrograph volumes (L/d)														
Regular flow	1090	697	507	169	293	190	1513	3057	1187	1490	1076	395	0	333	302
Leakage & base flow	374	302	274	216	202	302	1512	3053	1195	1498	1080	216	0	331	302
TOTAL FLOW	1464	999	780	385	495	492	3025	6109	2382	2988	2156	611	0	664	605

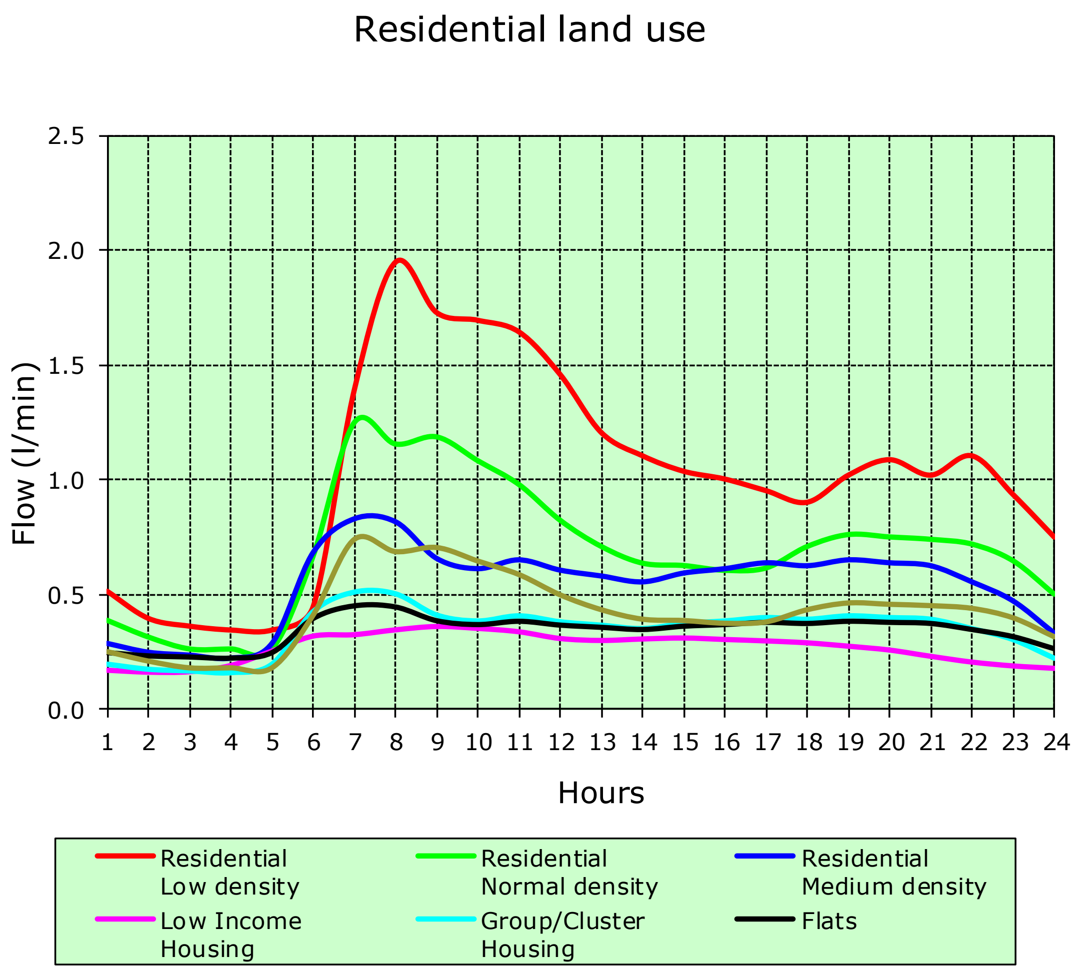


Figure K.17: Hourly flow ordinates relative to Hydrograph Peak (residential land use)

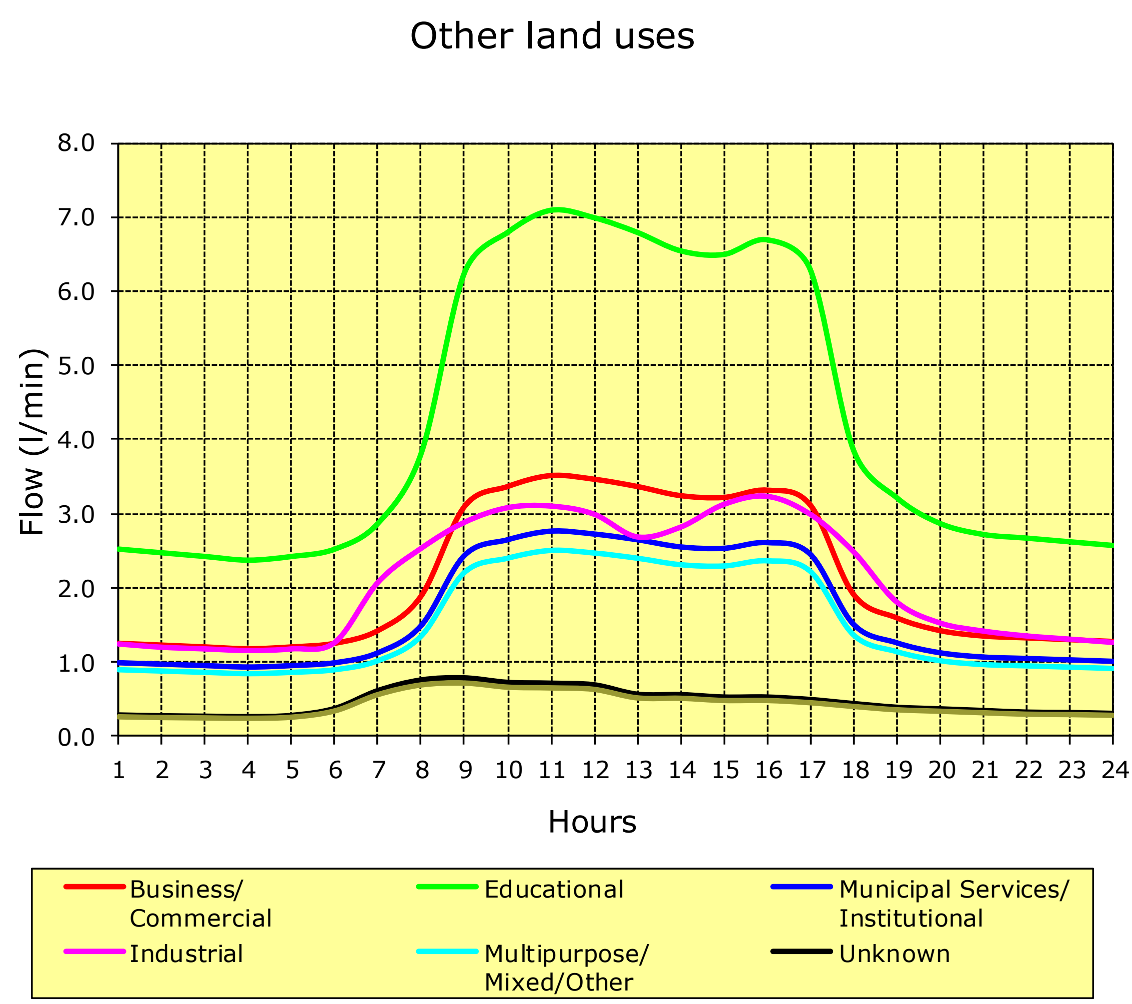


Figure K.18: Hourly flow ordinates relative to Hydrograph Peak (other land uses)

Table K.6: Worked example S1 – Unit hydrograph method			
Input Data and data from Table K.4 and Table K.5			
Land use #1	Medium-density residential	Business and commercial	Total
Number of units [EE] #1	50	30	
Unit hydrograph type #2	UH3	UH7	
Peak flow (L/min) #3	0.64	2.46	
Leakage and base flow (L/min) #3	0.19	1.05	
Unit PDDWF [UQ] (kL/d/unit) #2	0.60	0.52	
Peak day factor #1			1.1

Table K.6: Worked example S1 – Unit hydrograph method							
Calculations (Regular flow + leakage and base flow)							
Hour [t]	Unit hyd. values #3 [UH]	Unit flow [HQ] (L/min/unit)	Flow [TQ] (L/s)	Unit hyd. values #3 [UH]	Unit flow [UQ] (L/min/unit)	Flow [TQ] (L/s)	Total flow (L/s)
1	0.15	0.286	0.183	0.08	1.247	0.107	0.290
2	0.09	0.248	0.159	0.07	1.222	0.105	0.264
3	0.07	0.235	0.150	0.06	1.198	0.103	0.253
4	0.05	0.222	0.142	0.05	1.173	0.101	0.243
5	0.15	0.286	0.183	0.06	1.198	0.103	0.286
6	0.77	0.683	0.437	0.08	1.247	0.107	0.545
7	1.00	0.830	0.532	0.15	1.419	0.122	0.654
8	0.98	0.817	0.524	0.34	1.886	0.162	0.686
9	0.73	0.657	0.421	0.83	3.092	0.266	0.687
10	0.66	0.612	0.392	0.94	3.362	0.289	0.681
11	0.72	0.651	0.417	1.00	3.510	0.302	0.719
12	0.65	0.606	0.388	0.98	3.461	0.297	0.686
13	0.61	0.580	0.372	0.94	3.362	0.289	0.661
14	0.57	0.555	0.355	0.89	3.239	0.278	0.634
15	0.63	0.593	0.380	0.88	3.215	0.276	0.656
16	0.66	0.612	0.392	0.92	3.313	0.285	0.677
17	0.70	0.638	0.409	0.84	3.116	0.268	0.677
18	0.68	0.625	0.401	0.35	1.911	0.164	0.565
19	0.72	0.651	0.417	0.22	1.591	0.137	0.554
20	0.70	0.638	0.409	0.15	1.419	0.122	0.531
21	0.68	0.625	0.401	0.12	1.345	0.116	0.516
22	0.57	0.555	0.355	0.11	1.321	0.114	0.469
23	0.44	0.472	0.302	0.10	1.296	0.111	0.414
24	0.22	0.331	0.212	0.09	1.271	0.109	0.321
Hydrograph PDDWF (kL/d/unit)		0.780			3.025		
IPDWF (excl. infiltration) (L/s)			0.532			0.302	0.719
PDDWF (excl. infiltration) (kL/d)			30.0			15.6	45.6
ADDWF (excl. infiltration) (kL/d)			27.3				41.5

Notes:

#1 - Example input data

#2 - Obtain from Table K.4 : Demands and hydrographs for different land use categories

#3 - Obtain from Table K.5 : Sewer unit hydrographs

Figure K.19: Worked example S1: Outflow hydrograph

Note: A peak factor is already included in the hydrograph used to calculate the flows. Therefore a seperate peak factor does not need to be applied.

(ii) AADD Method

The AADD method, as opposed to the unit hydrograph method, uses the actual or theoretical average annual daily demand (AADD), calculated per land use, to determine the sewage flow in the pipe at any time ('t'). This method can only be used if the AADD is known. This is a more accurate method as it gives a more realistic view of the flow pattern. The flow is calculated using the following formulae:

$$HQ_t \text{ (L/min/unit)} = UH_t \times \text{Peak} + \text{Leak}$$

$$\text{Unit } PDDWF \text{ (kL/d/unit)} = \tfrac{1}{24} \textstyle\sum_{t=1}^{24} HQ_t \times (24 \text{ h} \times 60 \text{ min}) \div 1000 \text{ L}$$

$$TQ_t \text{ (L/s)} = HQ_t \times \left(\frac{AADD \text{ (kL/d/unit)} \times \text{Ratio} \div 100 \times 1000 \text{ L} \div (24 \text{ h} \times 60 \text{ min})}{\frac{1}{24} \sum_{t=1}^{24} HQ_t \text{ (L/min/unit)}} \right) \times EE \div 60 \text{ sec}$$

Where:

UH_t = Unit hydrograph value for land use type at a specific time step (from Table K.5)
Peak = Hydrograph peak flow for land use type (from Table K.5) in L/min
Leak = Hydrograph leakage and base flow for land use type (from Table K.5) in L/min
UQ = Unit PDDWF for land use type (from Table K.4, second last column) in kL/d/unit
$AADD$ = Unit AADD for land use type (from Table K.4) in kL/d/unit
Ratio = The Ratio % of AADD (from Table K.4)
EE = Number of units or land parcels per land use type
HQ_t = Calculated unit flow at a specific time step for land use type in L/min/unit
TQ_t = Calculated flow at a specific time step for land use type in L/s

Worked example S2 – AADD method

This worked example describes the AADD method to determine the flow for 50 medium-density residential (UH2) units and 30 business/commercial property (UH7) units. The first two equations are the same as used for the Unit Hydrograph method to calculate unit flow and unit PDDWF, but the equation for TQt is slightly modified to incorporate the AADD adjustment. The input data is as obtained from Table K.4 and Table K.5 and the calculated values are shown in Table K.7.

Calculate for each hourly interval for the 'medium-density residential' land use type excluding infiltration:

Example: Calculation for hour 1 of 24-hour time step:

Unit Flow* (HQ_t) for hour 1	= UH_t x Peak + Leak
	= 0.15 x 0.64 L/min/unit + 0.19 L/min/unit
	= 0.286 L/min/unit
Calculated Unit *PDDWF**	= Average of HQ_t for the 24h period L/min/unit x (24 h x 60 min) ÷ 1 000 L
	= 0.542 (L/min/unit) x 24 h x 60 min ÷ 1 000 L
	= 0.780 kL/d/unit
Calculated *PDDWF** (UQ)	= *AADD* kL/d/unit x Ratio % ÷ 100
	= 1.00 kL/d/unit x 60% ÷ 100
	= 0.60 kL/d/unit
Flow* (TQ_t) for hour 1	= HQ_t L/min/unit x (*UQ* kL/d/unit ÷ Calculated Unit *PDDWF* kL/d/unit) x *EE* units
	= 0.286 L/min/unit x (0.60 kL/d/unit ÷ 0.78 kL/d/unit) x 50 units ÷ 60 sec
	= 0.183 L/s

Note: * Flow excludes infiltration

Calculate design flow for 'medium-density residential' land use type excluding infiltration:

*IPDWF**	= Maximum of Flow [*TQ*] over the 24h period
	= 0.532 L/s
*PDDWF**	= Average of Flow [*TQ*] over the 24h period x (24h x 60min) ÷ 1 000 L, or
	= Number of units [*EE*] x Unit *PDDWF* [*UQ*]
	= 50 units x 0.60 kL/d/unit
	= 30.0 kL/d
*ADDWF**	= *PDDWF* ÷ Peak day factor
	= 30.0 kL/d ÷ 1.1 factor
	= 27.3 kL/d

Note: * Flow excludes infiltration

Similarly, the flows for the 30 business/commercial (UH7) units can be calculated with the values shown in Table K.6.

Table K.7: Worked example S2 – AADD method

Input and data from Table K.4 and Table K.5			
Land use #1	Medium-density residential	Business and commercial	Total
Number of units (EE) #1	50	30	
Unit hydrograph type #2	UH3	UH7	
Hydrograph peak (L/min) #3	0.64	2.46	
Leakage and base flow (L/min) #3	0.19	1.05	
AADD (kL/d/unit) #2	1.00	0.65	
Ratio % of AADD #2	60%	80%	
Unit PDDWF [UQ] (kL/d/unit)	0.60	0.52	
Peak day factor #1			1.1

Calculations (Regular flow + leakage and base flow)							
Hour [t]	Unit hyd. values #3 [UH]	Unit flow [HQ] (L/min/unit)	Flow [TQ] (L/s)	Unit hyd. values #3 [UH]	Unit flow [UQ] (L/min/unit)	Flow [TQ] (L/s)	Total flow (L/s)
1	0.15	0.286	0.183	0.08	1.247	0.107	0.290
2	0.09	0.248	0.159	0.07	1.222	0.105	0.264
3	0.07	0.235	0.150	0.06	1.198	0.103	0.253
4	0.05	0.222	0.142	0.05	1.173	0.101	0.243
5	0.15	0.286	0.183	0.06	1.198	0.103	0.286
6	0.77	0.683	0.437	0.08	1.247	0.107	0.545
7	1.00	0.830	0.532	0.15	1.419	0.122	0.654
8	0.98	0.817	0.524	0.34	1.886	0.162	0.686
9	0.73	0.657	0.421	0.83	3.092	0.266	0.687
10	0.66	0.612	0.392	0.94	3.362	0.289	0.681
11	0.72	0.651	0.417	1.00	3.510	0.302	0.719
12	0.65	0.606	0.388	0.98	3.461	0.297	0.686
13	0.61	0.580	0.372	0.94	3.362	0.289	0.661
14	0.57	0.555	0.355	0.89	3.239	0.278	0.634
15	0.63	0.593	0.380	0.88	3.215	0.276	0.656
16	0.66	0.612	0.392	0.92	3.313	0.285	0.677
17	0.70	0.638	0.409	0.84	3.116	0.268	0.677
18	0.68	0.625	0.401	0.35	1.911	0.164	0.565
19	0.72	0.651	0.417	0.22	1.591	0.137	0.554
20	0.70	0.638	0.409	0.15	1.419	0.122	0.531
21	0.68	0.625	0.401	0.12	1.345	0.116	0.516
22	0.57	0.555	0.355	0.11	1.321	0.114	0.469
23	0.44	0.472	0.302	0.10	1.296	0.111	0.414
24	0.22	0.331	0.212	0.09	1.271	0.109	0.321
Hydrograph PDDWF (kL/d/unit)		0.780			3.025		

Hour [t]	Unit hyd. values #3 [UH]	Unit flow [HQ] (L/min/unit)	Flow [TQ] (L/s)	Unit hyd. values #3 [UH]	Unit flow [UQ] (L/min/unit)	Flow [TQ] (L/s)	Total flow (L/s)
IPDWF (excl. infiltration) (L/s)			0.532			0.302	0.719
PDDWF (excl. infiltration) (kL/d)			30.0			15.6	45.6
ADDWF (excl. infiltration) (kL/d)			27.3				41.5

Notes:

#1 - Example input data

#2 - Obtain from Table K.4 : Demands and hydrographs for different land use categories

#3 - Obtain from Table K.5 : Sewer unit hydrographs

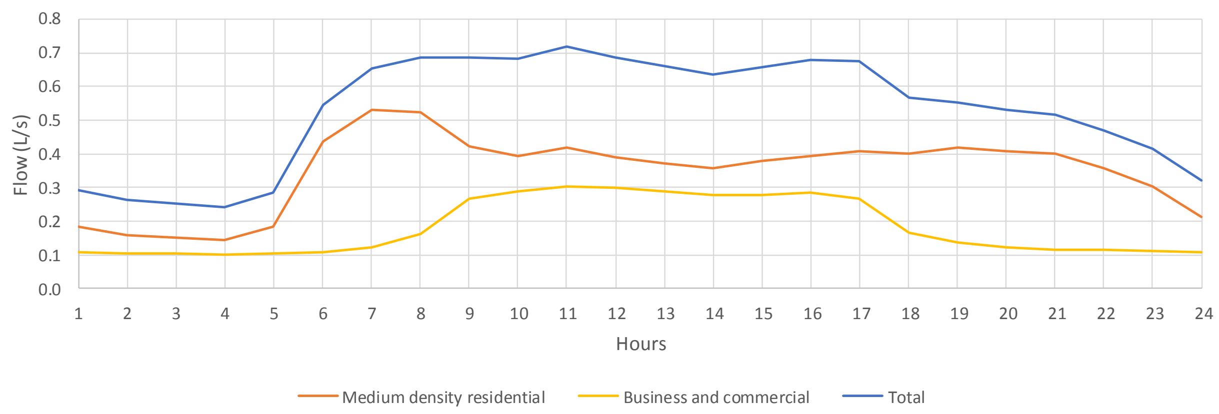


Figure K.20: Worked example S2: Outflow hydrograph

Note that a peak factor is already included in the hydrographs used to calculate the flows and therefore a separate peak factor does not need to be applied.

(iii) Sewer flow and peak factor method

This method uses the Peak Daily Dry Weather Flow (PDDWF) and applies a peak factor to determine the peak flow. Table K.4 should be used to determine the unit PDDWF. The total PDDWF is calculated as the sum of the unit PDDWF for the respective land uses and number of units/stands for the design area, as calculated below.

A peak factor should be used to determine the peak flow. Typical design peak factors are provided in Table K.8 for various land uses. Figure K.21 provides a graph to select the peak factor for the residential zone based on the anticipated population. Consult with the local authority to obtain specific peak factors, if available.

Table K.8: Peak factors	
Land use	Peak factor
Residential – see Figure K.16	1.8 to 2.5
Business/commercial	1.3 to 1.5
Industrial – light	2.5 to 4.0
Industrial – heavy	2.0 to 3.0
Clinics, restaurants, laundromats and hotels	1.8 to 2.5

Note:
This method does not use the hydrograph peak, and thus a peak factor needs to be applied.

The peak flow rate, IPDWF (excluding infiltration), should be calculated as follows for each land use category:

$IPDWF$ (excl. infiltration) (L/s) = Number of units [EE] × $PDDWF$ (kL/d/unit) × PF × 1 000 ÷ (24 h × 60 min × 60 sec)

$PDDWF$ (excl. infiltration) (kL/d) = Number of units [EE] × Unit $PDDWF$ [UQ] (kL/d/unit)

$ADDWF$ (excl. infiltration) (kL/d) = $PDDWF$ (kL/d) ÷ Peak day factor

Where:

PF = Peak factor (from Table K.8)
UQ = Unit PDDWF for land use type (from Table K.4, second last column) in kL/d/unit
EE = Number of units or land parcels per land use type

Use Figure K.21 for selecting a peak factor for residential areas where the anticipated population is known. The peak factor reduces due to attenuation of peak flows in gravity sewer systems as the contributor area and population increase. The maximum recommended peak factor for residential areas is 2.5. If actual local peak factors are available, these should be used instead.

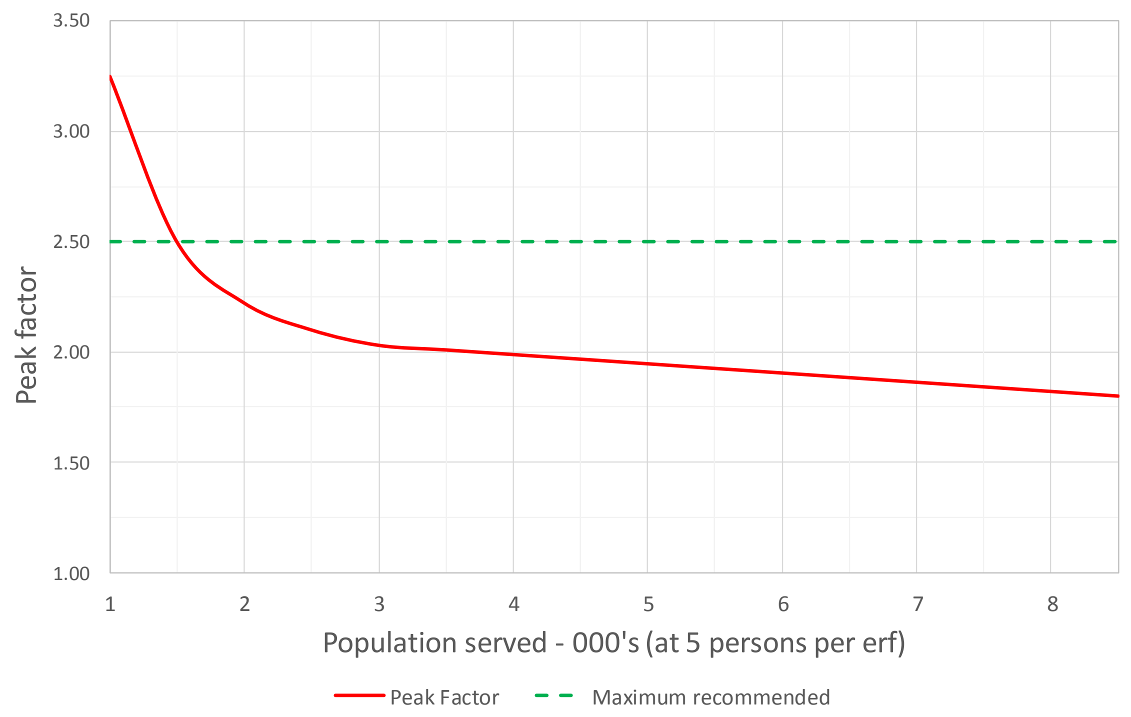


Figure K.21: Peak factors for residential land use

<u>Worked example S3 – Sewer flow and peak factor method</u>

The same land-use categories and units are used for this worked example as for the examples above.

Table K.9: Worked example S3 – Sewer flow and peak factor method

Input and data from Table K.4, Table K.8 and Figure K.16			
Land use #1	Medium-density residential	Business and commercial	Total
Number of units [EE] #1	50	30	
Unit PDDWF [UQ] (kL/d/unit) #2	0.60	0.52	
Persons per unit #3	5	n/a	
Peak factor #3	2.5	1.50	
Peak day factor #1			1.1
Calculations			
Total number of persons	250	n/a	
IPDWF (excl. infiltration) (L/s)	0.868	0.271	1.139
PDDWF (excl. infiltration) (kL/d)	30.0	15.6	45.6
ADDWF (excl. infiltration) (kL/d)	27.3	14.2	41.5

Notes :

#1 - Example input data

#2 - Obtain from Table K.4: PDDWF (excluding infiltration) for different land use categories

#3 - Obtain from Table K.8: Peak factors and Figure K.16: Peak factors for residential land use

Comparing this to the flows as determined from the previous two methods, the design flow calculated from the peak factor method is much higher. This is because this method does not account for the difference in the timing of the peak, which does not occur at the same time for the Unit Hydrograph and AADD Method.

Calculate design flow for 'medium-density residential' land use type excluding infiltration:

Total number of persons	= Number of units [*EE*] × persons per unit
	= 50 units × 5 persons per unit
	= 250 persons
Peak factor	= From Figure K.16 (or Table K.8)
	= 2.5
*IPDWF**	= 50 units × 0.60 kL/d/unit × 2.5 Peak factor x 1 000 L ÷ (24h x 60min × 60sec)
	= 0.868 L/s
*PDDWF**	= Number of units [*EE*] × Unit *PDDWF* [*UQ*]
	= 50 units × 0.60 kL/d/unit
	= 30.0 kL/d
*ADDWF**	= *PDDWF* ÷ Peak day factor
	= 30.0 kL/d ÷ 1.1 factor

Where:

EE = Number of units or land parcels per land use category
UQ = Unit PDDWF for land use category (from Table K.4, second last column) in kL/d/unit

Note: * Flow excludes infiltration

K.4.2.2 Groundwater infiltration

Typically, 35% of the total base flow measured in sewers is due to groundwater infiltration through joints and cracks in the sewer pipe system. Assuming this to be the case, a groundwater infiltration rate of between 0.03 and 0.04 *(L/min/m pipe/m Ø)* should be allowed for (see Table K.10).

The infiltration is dependent on the length of the pipe and the outside diameter of the pipe. This is because the outside of the pipe is exposed to the ground. Where the total pipe length is unknown, use Table K.11 to estimate the sewer pipe lengths per stand (or unit) for different land use types. Multiply the unit pipe length with the proposed number of stands to obtain an indicative total pipe length (reticulation) for a proposed development. Separate allowance should be made for bulk or collector outfall sewers based on site-specific conditions. Due to the wide range of possible stand sizes for business/commercial units, the pipe lengths should be calculated using site-specific conditions.

Table K.10: Groundwater infiltration	
Condition	Infiltration *(L/min/m pipe/m Ø)*
Minimum groundwater infiltration	0.03
Maximum groundwater infiltration	0.04

Table K.11: Typical pipe length (reticulation) per stand/plot			
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 1 000	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
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] - Assumed net area factor = 0.8 x gross area (20% allowance for roads, servitudes and open spaces)

[#2] - Calculation based on a square shape stand/plot

Worked example S4 – Groundwater infiltration

For the proposed development comprising 50 medium-density residential units and 30 business/commercial units (as was used in previous examples), the total sewer pipe length should be estimated from Table K.11 as follows:

For the medium-density residential category, estimate the pipe length from Table K.11 = 15m x 50 units = 750 m

For the business/commercial units category, estimate the pipe length (assumed length) = 250 m
Total pipe length = 1 000 m

Assume that all reticulation is 150 mm Ø with no further allowance needed for bulk or collector outfalls. The groundwater infiltration can thus be calculated using the following formula with the results as indicated in Table K.12:

$$\text{Infiltration flow (L/s)} = \text{Infiltration rate (L/min/m/m)} \times \text{Pipe length (m)} \times \text{Pipe diameter (m)} \div 60 \text{ sec}$$

Table K.12: Worked example S4 – Groundwater infiltration		
Input data		
Pipe length (m) #1	1000	
Pipe inside diameter (mm) #1	150	
Infiltration rate (L/min/m pipe/m Ø) #2	0.04	
Calculations - Infiltration		
	Peak flow (L/s)	Daily flow (kL/d)
Groundwater infiltration flow	0.100	8.6

Notes:

#1 - Example input data (See Table K.11)

#2 - See Table K.10 for recommended groundwater infiltration

The groundwater infiltration flow should be calculated as follows:

Groundwater infiltration flow = 0.04 L/min/m/m x 1 000 m x (150 mm ÷ 1 000) ÷ 60 sec
= 0.100 L/s
= 0.10 L/s x (24 h x 60 min x 60 sec ÷ 1 000
= 8.6 kL/d

K.4.2.3 Allowance for stormwater ingress

Gravity sewers should be sized not only to accommodate the peak flow during dry weather conditions (IPDWF incl. infiltration), but a spare capacity allowance should be provided for to accommodate stormwater ingress as was illustrated in Figure K.16. The percentage spare capacity allowance criteria for stormwater ingress are to be obtained from the local authority. In the absence of such local criteria, use 30% as recommended for reticulation, and between 15% and 30% as recommended for outfall sewers. Refer to the following section for the calculation.

K.4.2.4 Design flow calculation

The calculation of the design flow or IPWWF (instantaneous peak wet weather flow), as detailed in preceding sections, can be summarised as follows:

Step 1: Calculate the IPDWF (instantaneous peak dry weather flow) excluding groundwater infiltration (Section K.4.2.1)

Step 2: Calculate the groundwater infiltration (Section K.4.2.2)

Step 3: Calculate the IPDWF (instantaneous peak dry weather flow) including groundwater infiltration as follows:

$$IPDWF\text{ (L/s)} = IPDWF\text{ (excl. Infiltration) (L/s)} + \text{Infiltration flow (L/s)}$$

Step 4: Calculate the design flow or IPWWF (instantaneous peak wet weather flow) as follows:

$$\text{Design Flow or } IPWWF\text{ (L/s)} = \frac{IPDWF\text{ incl infiltration (L/s)}}{(1 - \text{spare capacity for stormwater ingress})}$$

K.4.3 Hydraulic design guidelines for waterborne sanitation systems

K.4.3.1 Hydraulic spare capacity calculation

The different spare capacity types are illustrated in Figure K.22.

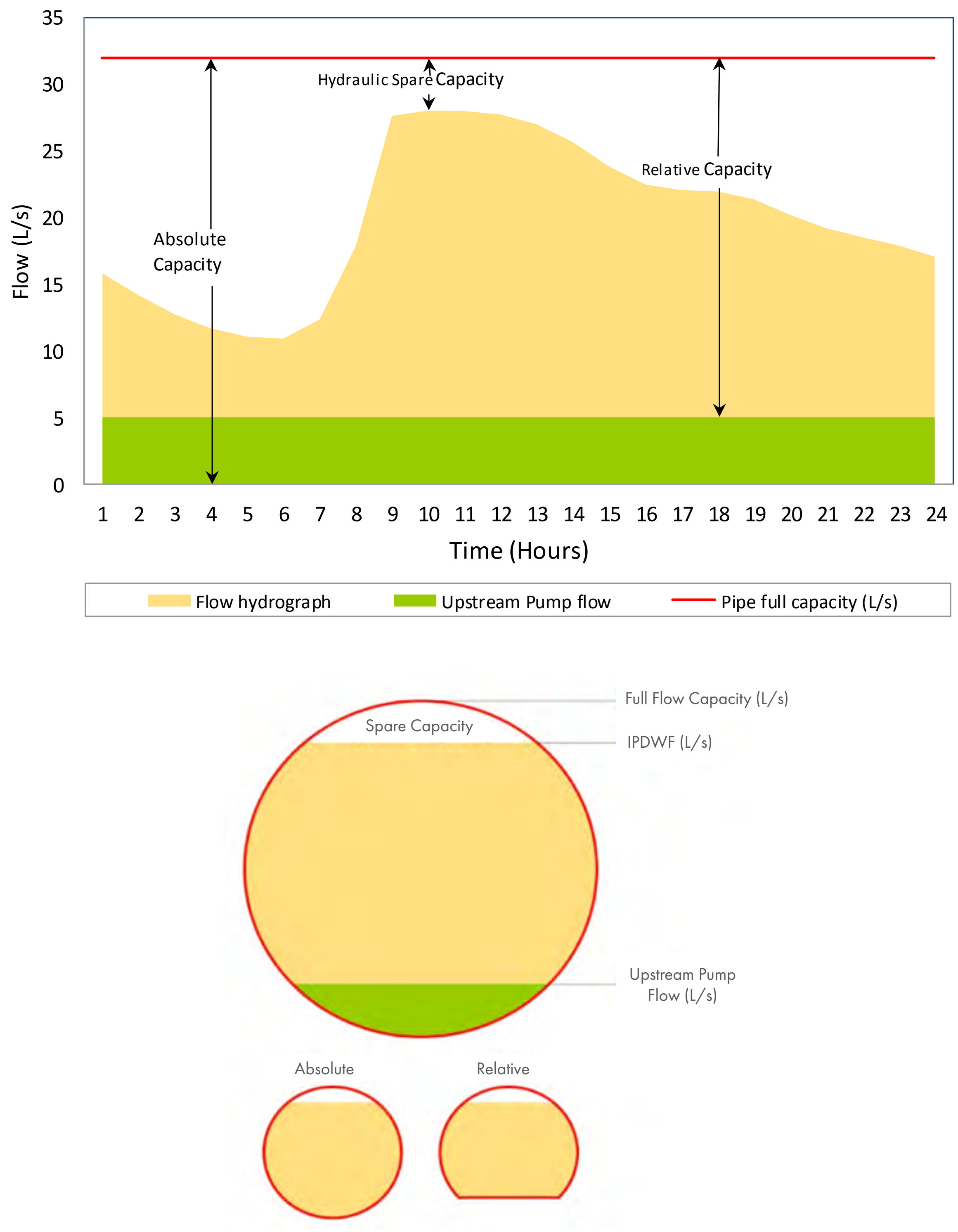


Figure K.22: Absolute and relative spare capacity

The 'spare capacity' for a regular pipe in a gravity system, which is unaffected by upstream pumps, is defined as follows:

$$\text{Absolute spare capacity (\%)} = \frac{\text{Full flow pipe capacity (L/s) - Max flow } (\mathit{IPDWF}) \text{ (L/s)}}{\text{Full flow pipe capacity (L/s)}}$$

The relative spare capacity is the spare hydraulic capacity expressed as a percentage of the relative capacity, which is the capacity of the pipe less the total upstream continuous pump flow rate.

If there are pumps upstream that pump at a continuous rate, it is necessary to consider the relative effect of these pumps on the spare capacity in the downstream pipes. Part of the capacity should cater for the continuous pump flow. Any spare capacity should be expressed as a percentage of the remaining available capacity, i.e. the relative capacity of the pipe, which is the total capacity less the effect of the upstream pumps.

$$\text{Relative spare capacity (\%)} = \frac{\text{Full flow pipe capacity (L/s) - Max flow } (\mathit{IPDWF}) \text{ (L/s)}}{\text{Full flow pipe capacity (L/s) - Upstream continuous pump rate (L/s)}} \text{ x } 100$$

It should be noted that in the case of variable speed pumps, the amount of flow that flows into the pump structure is pumped out, unless the flow is more than the capacity of the pump; then it overflows. For continuous speed pumps, the pump flow rate is constant, regardless of the inflow.

Worked example S5: Hydraulic capacity

The example below shows that spare capacity is below 30%, assuming this is the minimum hydraulic spare capacity allowance for stormwater ingress. Thus the pipe is too small and should be upgraded.

If the upstream continuous pump flow rate is excluded, the relative spare capacity is more than 30%. Thus no upgrade is required.

Table K.13: Worked example S5 – Hydraulic capacity

Input data	
Pipe's full-flow capacity (L/s) #1	32.0
Max flow (IPDWF) (L/s) #1	28.0
Total upstream continuous flow rate (L/s) #1	20.0
Spare capacity required #1	30%
Calculations	
Absolute spare capacity	
Spare capacity (L/s)	4.0
Available	12.5%
Relative spare capacity	
Spare capacity (L/s)	4.0
Max flow (IPDWF) excluding continuous pump flow rate (L/s)	8.0
Available	33.3%

Note:

#1 - Example input data

K.4.3.2 Velocity calculation

(i) Gravity sewers

The following flow formulae are used for the calculation of velocity and flow in sewers pipe sections during normal depth conditions (slope of the water surface and channel bottom is the same and the water depth remains constant).

Table K.14: Flow formulae

Formula name	Formula	Roughness constant
Mannings	$Q = VA = \frac{1}{n} AR^{\frac{2}{3}}\sqrt{S}$	$(n = 0.012)$
Chezy	$Q = VA = 18log \frac{12R}{k_S} A\sqrt{RS}$	$(K_S = 0.600)$
Colebrook-White	$\frac{1}{\sqrt{f}} = -2log_{10} (\frac{\varepsilon}{3.7D_H} + \frac{2.51}{Re\sqrt{f}})$	
Kutter	$C = \dfrac{23 + \frac{0.00155}{S_0} + \frac{1}{n}}{1 + \frac{n}{\sqrt{R}}\left(23 + \frac{0.00155}{S_0}\right)}$ $V = C\sqrt{RS}$	$(n = 0.012)$

Where:

A = Cross-sectional area of flow/conduit (m^2)
R = Hydraulic radius (m)
S = Gradient (assuming uniform flow)
n = Manning's roughness coefficient – dependent on material type
k_S or ε = Absolute roughness of conduit (m)
C = Chezy roughness coefficient
f = Darcy-Weisbach friction factor
D_H = Hydraulic diameter (m)
Re = Reynolds number

These formulae are used assuming full flow in the pipe. Any of the above formulae can be used as long as they produce values approximately the same as the equivalent Colebrook-White formula that uses a K_S of 0.6. For modelling purposes, the general Manning roughness coefficient is 0.012, but it is dependent on the pipe material and condition.

For partially full pipes, the partial flow diagram (see Figure K.23) can be used to calculate the flow and velocity based on proportions of the full-flow velocity and discharge, as well as the depth of flow.

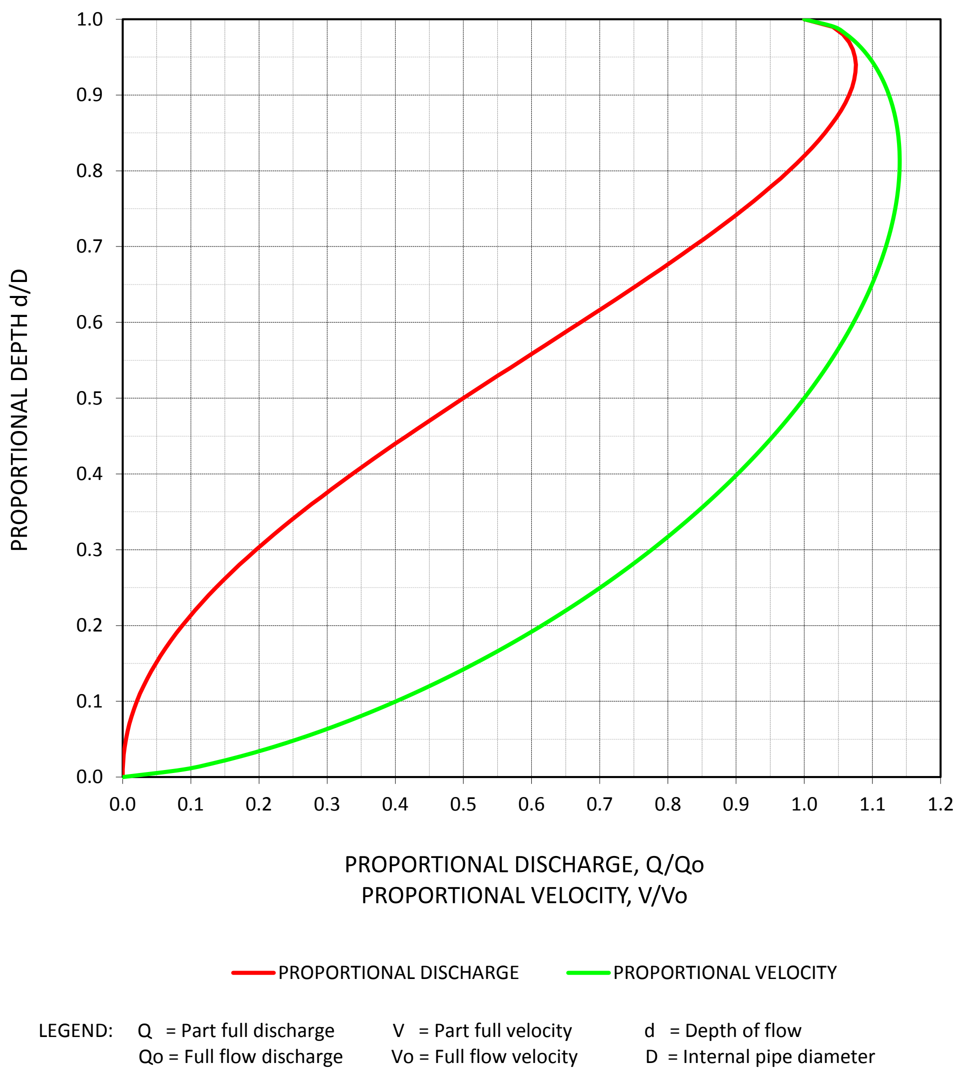


Figure K.23: Partial flow diagram

(ii) Rising (pumped) sewers

For pumped sewers flowing full, the pipe velocity is calculated as follows:

$V = Q/A$

Where:

V = Pipe Velocity (m/s)
Q = pumped flow rate (capacity) in m^3/s
A = Cross-sectional area of the sewer (m^2)

For circular sewers it is calculated as follows:

$A = \pi Ø^2/4$

Where Ø = pipe diameter (m)

K.4.3.3 Gravity sewer system

The following design criteria are recommended for gravity sewers:

(i) Gravity main – minimum and maximum flow velocities and gradients

Sewers may follow the general slope of the ground, provided that a minimum full-bore velocity of 0.6-0.7 m/s is maintained at the minimum gradient in all gravity mains. This is to ensure that sufficient scouring of the mains takes place.

The maximum flow velocity under full-flow conditions should be not more than 2.5 m/s to prevent damage to the pipelines, although a higher flow velocity of up to 3.5 - 4.0 m/s may be acceptable over short pipe lengths and for short periods. The maximum pipe velocity should be checked with the pipe manufacturer. Too high velocities should be avoided due to separation and abrasion.

Table K.18 shows absolute minimum gradients for different diameter pipes required to achieve the minimum full-bore velocity of 0.65 m/s. If flatter grades and lower velocities are considered, it is essential that a detailed cost-benefit study be conducted. The cost of the regular, systematic maintenance and silt/sand removal that will be required when flatter grades and lower velocities are used, will need to be compared to the additional capital cost required to maintain the above minimum grades at full-bore velocity of 0.6 - 0.7 m/s.

The diameters in Table K.15 are for illustrative purposes only. The actual Manning coefficient of the pipe should be obtained from the pipe manufacturer to calculate the minimum gradient to achieve the required minimum velocities of 0.65 m/s.

Table K.15: Minimum gradients for ±0.65 m/s full flow velocity (more than 21 units[#1])

Pipe diameter			Class	Material (general)	Minimum gradient [#1] (Manning n = 0.012)	Flow @ 70% (L/s)
Nominal (mm)	Outside (mm)	Inside (mm)				
110	110	104	34	uPVC	1 : 120	4
160	160	151	34	uPVC	1 : 200	8
200	200	188	34	uPVC	1 : 250	13
250	250	235	34	uPVC	1 : 350	20
315	315	297	34	uPVC	1 : 500	32
355	355	334	34	uPVC	1 : 600	40
450	533	416	100D	Concrete	1 : 700	51
525	616	534	75D	Concrete	1 : 800	62
600	699	611	75D	Concrete	1 : 1 100	103
675	787	685	75D	Concrete	1 : 1 300	136

Table K.15: Minimum gradients for ±0.65 m/s full-flow velocity (more than 21 units[#1])

Pipe diameter			Class	Material (general)	Minimum gradient [#1] (Manning n = 0.012)	Flow
Nominal (mm)	Outside (mm)	Inside (mm)				@ 70% (L/s)
750	870	762	75D	Concrete	1 : 1 500	171
825	946	830	75D	Concrete	1 : 1 800	208
900	1 041	913	75D	Concrete	1 : 2 000	247
1 050	1 194	1 066	50D	Concrete	1 : 2 300	297
1 200	1 365	1 219	50D	Concrete	1 : 2 800	407
1 350	1 524	1 372	50D	Concrete	1 : 3 400	529
1 500	1 689	1 523	50D	Concrete	1 : 4 000	668
1 650	1 878	1 700	50D	Concrete	1 : 4 600	823
1 800	2 019	1 803	50D	Concrete	1 : 5 300	1 028

[#1] When the number of upstream units exceeds 21, the minimum slope as provided above should be used for the corresponding diameter when assuming the Manning coefficient is 0.012. For pipes servicing fewer than 21 units, the gradients as shown in Table K.16 should be used.

The sewer pipes should have a steeper gradient closer to the upper end of the sewer network to ensure the pipes are cleared and that settlement is avoided, as the pipes do not flow full regularly and low-flow conditions can occur (depth of flow less than 20% of the diameter). Minimum gradients based on the number of upstream units are listed in Table K.16 to ensure sufficient pipe flushing. House connections should be laid at a minimum slope of 1:60 for 110 mm nominal diameter pipes.

Table K.16: Preferred and minimum gradients for upper end of sewer network (less than 21 units)

Number of units	110 mm – Nominal diameter		160 mm – Nominal diameter	
	Preferred gradient	Minimum gradient	Preferred gradient	Minimum gradient
1 to 10	1 : 60	1 : 75	1 : 80	1 : 100
11 to 20	1 : 75	1 : 100	1 : 100	1 : 140
21 and more	1 : 90	1 : 120	1 : 120	1 : 200

(ii) Gravity main – minimum size/diameter

The minimum permissible diameter for gravity sewer pipes in a municipality should be at least 150 mm inside or nominal diameter, but the absolute minimum diameter of the pipe in sewer reticulation should be 100 mm (connections to properties).

A minimum pipe diameter of 200 mm (outside) is recommended for CBD developments. This is to provide some spare capacity for future densification, because of the difficulty of installing additional services in the CBD.

K.4.3.4 Pumped sewer system

Sewer pumping stations should only be considered where absolutely necessary, and where a gravity alternative is not feasible. A sewer pump station should consist of a sump to receive incoming sewage, and pumps that pump the sewage through a rising main into a downstream stilling chamber. The design recommendations for each of these four components are provided below.

(i) Sizing of sumps

The sump receives the sewage flow and acts as a storage vessel from where sewage is periodically pumped. The sump comprises an active and emergency storage volume. The active volume is defined by the operating levels of the sump. The emergency storage volume provides additional safety when the pumps fail, in that it provides time for the maintenance crew to make repairs before an overflow happens. The calculation of the emergency and active sump volume is detailed below.

a. Emergency storage

A minimum emergency storage capacity should be provided representing a capacity that is equivalent to four to six hours' flow at the design flow rate, over and above the capacity available in the sump at normal top-water level (i.e. the level at which the duty pump cuts in). This provision applies only to pump stations serving less than 250 dwelling units and where no backup power for pump stations is supplied. The aim is to contain any sewage spillage.

For pump stations serving larger numbers of dwelling units, the sump capacity should be subject to special consideration, in consultation with the local authority concerned. Emergency storage may be provided inside or outside the pump station. Emergency sump volume is calculated using the following formula:

$$V_E = q \times T_E$$

Where:

T_E = minimum emergency storage time (specified by local authority – generally 4 to 6 hours)
q = average raw sewage inflow rate (ADDWF)
V_E = sump emergency storage volume (m^3)

Some emergency storage capacity might also be available in the up-stream gravity lines and manholes.

b. Active sump volume

Active sump volume is calculated using the following formula:

$$T = \frac{V_A}{q} - \frac{V_A}{(Q - q)}$$

Where:

T = Minimum cycle between pump starts (time to fill + time to empty)
V_A = Sump active volume (m^3/s)
Q = Pumping rate
q = Sewage inflow rate

The total sump volume is the sum of the active and emergency volumes:

$$V = V_A + V_E$$

c. Buoyancy calculations

Ensure that the structure will not float when subjected to high groundwater levels.

(ii) Sizing of pumps

Pumps are mechanical equipment used to transfer sewage from the sump to a higher location within the sewer system. The selection of the pumps depends on the hydraulic requirements they must meet and the level of safety the design requires.

a. Design flow

The capacity of the pumping station should equal or exceed the instantaneous peak wet weather flow (IPWWF) that arrives at the pumping station to allow for stormwater ingress. In the case of a 30% stormwater allowance, the pump should have a capacity equal to the design flow, generally:

$$\frac{IPDWF}{(1-0.3)} = \frac{IPDWF}{0.7} = 1.43 \times IPDWF$$

b. System hydraulics

The pumping station should be designed to operate under the full range of projected system hydraulic conditions. The system should be designed to prevent a pump from operating for long periods of time beyond the pump manufacturer's recommended normal operating range. Start/stop cycles should not exceed the pump motor manufacturer's recommendation.

The pump station should be designed in such a way that the pumps operate a maximum of two duty cycles per hour during average flow conditions and not more than six cycles per hour during instantaneous peak wet weather flow.

c. Efficiency

Pumps should be selected to ensure that the operating point is near the maximum efficiency point on the pump performance curve, within the pump's recommended operating range, and within the manufacturer's recommended limits for radial thrust and vibration.

d. Standby pumps

Pumping stations should be designed to accommodate instantaneous peak wet weather flow (IPWWF), with at least one reserve pump. At least two pumps should be installed, each capable of pumping at a flow rate more than the peak wet weather flow (for emergency purposes), but at the same time, taking care not to provide excessive standby capacity. The standby pump should come into operation automatically if a duty pump or its driving motor fails.

Where three or more pumps are selected, they should be designed to fit actual flow conditions and must be so designed so that with any one pump out of service, the remaining pumps will have the capacity to pump the IPWWF. Pumps should be designed in such a way that one pump can empty the sump plus handle the average inflow in less than 30 minutes.

e. Hydraulic influence of pump stations

Although sewer pump stations operate intermittently, their flows can influence the hydraulics of the downstream pipes at any time during the day. It is therefore advised to model the pumps as 'continuous' pumps that pump for 24 hours per day when sizing downstream gravity sewers.

f. Surge analysis

Consider hydraulic surges and transients (water hammer) during the design of pump stations and pumping mains.

g. Cavitation

Ensure that the Net Positive Suction Head (NPSH) available is higher than the NPSH required to avoid cavitation damage to the pump.

h. Backup power for pump stations

Emergency power supply should be provided to pumping stations to ensure continuous operation when primary electrical supply is out of service (standby generator). Larger pump stations should have permanent diesel-oil-fuelled, engine-driven generator units with automatic transfer switches to transfer the electrical feed from the primary to the standby unit when a power failure is detected by the instrumentation and control system, sized to operate all electrical components. For smaller pump stations, where a dedicated backup generator is not available, a portable generator should be available. A manual transfer switch and an emergency plug-in power connection to the station, for use with the portable generator, should in these cases be installed. A standby generator should be provided to supply the pump station with full load power for at least 6 hours.

i. Pump sizing and design

The appropriate pump should be selected by considering the pump system curves. The pump system curves indicate the interaction between the pump performance and the pumping main used to deliver the discharge. The pumping system curves should be determined in the selection of the pumps to ensure an appropriate and efficient pumping system.

Every pump manufacturer has a pump performance curve for every pump. The pump performance curve shows the discharge relative to the pressure for a particular pump and impeller size (diameter). It also shows the efficiency, as illustrated below. The system curve (which represents the static head and the friction losses of the pumping main) should be used in conjunction with the pump performance curve to specify the most appropriate pump that can accommodate the flow and provide the required head at the desired efficiency. The operating (duty) point is where the pump performance curve and system curve intersect. The duty point should be near the pump's best efficiency point (BEP), as is shown in Figure K.24.

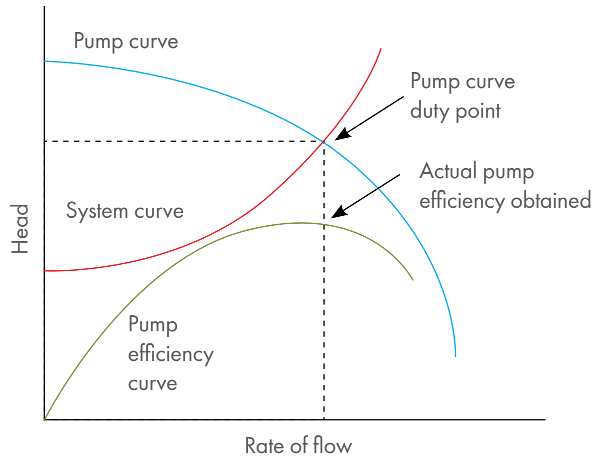


Figure K.24: Pumping system curve

The following should be considered when selecting the correct pump:

- The pump should be selected to ensure that the duty specified falls well within the stable range of the head/quantity characteristic curve of the pump.
- The pump should have a non-overloading power curve.
- Maximum suction lift should not exceed the pump manufacturer's recommendations and should be based on a net positive suction calculation with an allowed factor of safety.

(iii) Rising mains

Rising mains should be designed to take care of the following:

- **Minimum and maximum flow velocities:** The minimum velocity of flow in a rising main should be 0.6 m/s. Flow velocities must be limited to protect pipeline coatings and reduce the effects of water hammer. The preferred maximum allowed is 1.5 to 1.8 m/s, but an absolute maximum of 2.5 m/s is acceptable where only intermittent peak flows occur.
- **Minimum size/diameter:** The minimum internal diameter of a rising main should be 100 mm, except where a macerator system is used, in which case the diameter can be reduced to 75 mm.

Other issues to consider when designing a rising main include:

- Where possible, the rising main must have a positive grade with no low points or high points so as to avoid possible gas release and grit deposition.
- Scour valves and air valves must be avoided at all cost.
- Protect the pipeline against hammer and surge forces (analyse and provide protection).
- Turbulence must be avoided to prevent the release of H_2S gas at the outlet.
- Provide protection against unbalanced forces (thrust) where necessary (thrust blocks and support).

(iv) Stilling chambers

Stilling chambers should be provided at the heads of all rising mains, and should be designed so that the liquid level always remains above the soffit level of the rising main where it enters the chamber. Stilling chambers should preferably be ventilated.

K.4.4 General design guidelines for waterborne sanitation systems

K.4.4.1 Sewer pipes

(i) Location

Sewers should be sited to provide the most economical design, taking into account the topography (i.e. in road reserves, servitudes, parks, other open spaces, etc.). The minimum clear width to be allocated to a sewer in the road reserve should be 1.5 m.

a. Siting

Sewer pipes should be located in open areas, road reserves or municipal land where they may be easily accessed at all times, preferably on the lower side of the road. In road reserves, sewers should be installed between the stormwater drain and the plot boundary where applicable. In built-up areas, sewer pipes should preferably be located 1.2 to 1.5 m from the plot boundary. The positioning of infrastructure in municipal areas is often guided by municipal specifications and standards.

Mid-block sewers should be avoided as far as practically possible. Where the mid-block system is unavoidable, the sewer connections should not be installed deeper than 2 m and the main sewer should not be installed deeper than 3 m. If these depths are to be exceeded, a double system must be used. In cases where decision-making is difficult, a comparative estimate of costs with the double system must be made. When designing a double system, it is essential that close attention is paid to where other services, particularly stormwater drains, are crossed. Special permission is required for mid-block sewers if they cannot be avoided. Mid-block sewers are not recommended in townships with individual stands of less than 400 m^2 in area. The following aspects should be considered when routing sewers:

- The sewer should follow the natural fall of the ground
- The sewer should be laid next to those properties that will benefit most directly from the sewer
- Road crossings should be kept to a minimum
- All other municipal services should be taken into account when installing a new sewer
- There should be minimum interference with existing structures

b. Road crossings

Where a road crossing is unavoidable, consider using the following:

- Existing crossings, such as culverts and bridges, to avoid excavation and pipe jacking for ground crossings.
- Pipe jacking where applicable and acceptable.
- Encasement of sewers that cross under surfaced roads (existing tar roads) in concrete.

- Backfilling of trenches in accordance with relevant construction specifications. (The selected materials should be hand-compacted to a depth of at least 300 mm above the top of the pipe).

c. Dolomitic regions

The following publications can be consulted regarding dolomitic areas:

- *Appropriate Development Infrastructure on Dolomite: Manual for Consultants, Volume 1 and Volume 2, PW344*[54]
- Section 2.8 of Part 1 of the *Home Building Manual* as published by the National Home Builders' Registration Council (NHBRC)[55]
- Proposed method for dolomite land hazard and risk assessment in *SAICE Journal*[56]

(ii) Minimum depth and cover

Table K.17 provides the recommended minimum values of cover to the outside of the pipe barrel for main sewers.

Table K.17: Minimum values of cover for pipe locations

Pipe location	Cover
House connections	300 – 800 mm
Public open spaces and mid-blocks (servitude)	800 – 1 000 mm
Street reserve (sidewalks)	1 100 – 1 200 mm - below final kerb level
Roadways (trafficked areas)	1 200 – 1 400 mm - below final constructed road level

The combination of loading, pipe depth, pipe strength, and bedding type should be acceptable to the relevant authorities. Shallower depths can be used where the bedding and compaction are well controlled, especially in roadways. Depths of cover for house connections should be such that the pipelines are not compromised by excess loading. Lesser depths of cover may be permitted, subject to integrated design of all services, including trunk services allowed for in development plans. However, where the depth of cover in roads or sidewalks is less than 600 mm, or in servitudes less than 300 mm, the pipe should be protected from damage by the following options:

- The placement of cast-in-situ or precast concrete slab(s) over the pipe, isolated from the pipe crown by a soil cushion of 100-150 mm minimum thickness. The protecting slab(s) should be wide enough and designed to prevent excessive superimposed loads being transferred directly to the pipes (see Figure K.25).

or

- The use of structurally stronger pipes that are able to withstand superimposed loads at the depth concerned.

or

- In isolated cases, the placement of additional earth filling over the existing ground level where this is possible.

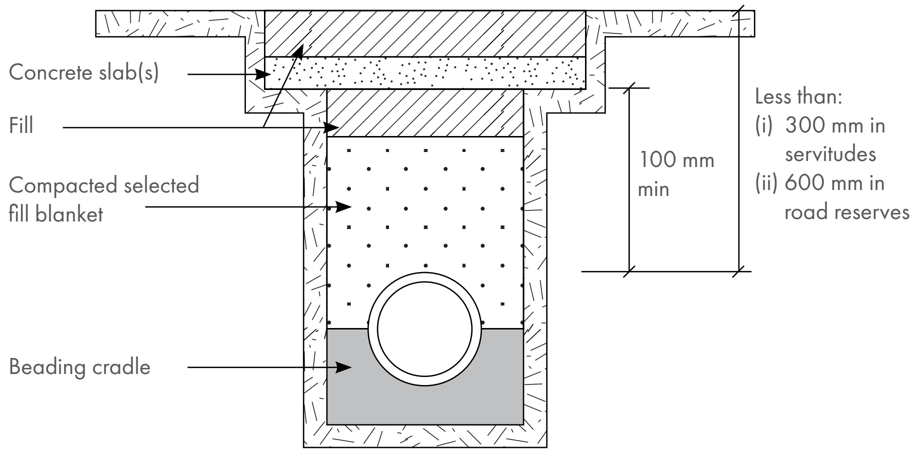


Figure K.25: Protection of pipes at reduced depths of cover (e.g. Class B bedding)

(iii) Trenching, bedding and backfilling

The trenching, bedding and backfilling for all sewers should be in accordance with the requirements of the relevant SABS standards and the local municipal requirements. A structural design of the pipe and bedding structure should be done where trenches are

- located under roads,
- deeper than 3 m, and/or
- other than those classified as 'narrow' (i.e. where overall trench width is greater than nominal pipe diameter – d + 450 mm for pipes up to 300 mm diameter).

The typical acceptable trench widths per outside pipe diameter are given in Table K.18.

Table K.18: Trench widths

Outside diameter (mm)	Trench width on each side of the pipe (mm)
<125	300
126 – 700	300
701 – 1 000	400
1 001 – 2 000	500
2 001 +	600

Pipes should be laid according to approved methods on the specified bedding to ensure trueness to line and level, and in such a manner that the barrels of pipes bear evenly on the bedding over their full length.

Spigot-and-socket pipes should be placed with the socket facing upstream. Pipes and joints should be laid in accordance with the manufacturer's instructions.

Pipes of 600 mm in diameter and larger should be kept clean on the inside by being swept by hand as laying progresses. The open ends of the pipelines should be closed at all times using approved plugs when laying is not in progress.

During all pipe-laying and bedding operations, care should be taken to prevent the entry of any dirt or concrete into the flexible pipe joints by sealing the joint with clay or other approved means.

The selected bedding and backfill material should be compacted to an optimum moisture content of at least 90% of modified AASHTO density.

After a pipeline has been laid, tested and approved, the trench should be partly backfilled (with hand implements), to a height of 300 mm above the top of the pipe barrel. Use suitable backfill material that contains sufficient fine material to ensure a densely graded, well-compacted backfill, but is free from stones exceeding 20 mm, organic matter, and lumps of clay exceeding 75 mm. Backfilling around and over the pipeline should be in layers not exceeding 100 mm compacted thickness. Backfilling should be carried out simultaneously and equally on both sides of the sewer to avoid unequal forces being exerted.

(iv) Anchoring – steep slopes

Concrete anchor blocks should be provided where grades are steeper than a ratio of 1:10 (or as otherwise required by the relevant local authority standards).

(v) Curved alignment

A straight alignment between manholes should normally be used, but curvilinear, horizontal or vertical alignment may be used where the economic circumstances warrant it, subject to the following limitations:

- The minimum radius of curvature is 30 m.
- Curvilinear alignment may be used only when approved flexible joints or pipes are used.
- In the construction of a steep drop, bent fittings may be used at the top and bottom of the steep short length of pipe, thus providing a curved alignment between the flat and steep gradients.

(vi) Encased pipes

The pipe can be encased for structural support or where the pipe is installed underneath a road (only where a slab has not been cast to support the pipe). Depression in the road should be prevented by ensuring the pipe does not deform under load. Where encasement is unavoidable, it should be made discontinuous at pipe joints in order to maintain joint flexibility.

(vii) Pipe load and deflection calculations

When designing pipe loads, it is important to investigate the loading (soil and imposed) on the pipe and any possible deflection. The calculations are dependent on the rigidity of the pipe.

- For flexible pipes (i.e. PVC pipes), the resultant deflection should be calculated for the applied loading conditions (soil and live load) and checked against manufacturer's allowable deflection.
- For rigid pipes (i.e. concrete), the applied load (soil and live load) should be calculated and checked against the load-carrying capacity tolerances as specified by the manufacturer.

The loading on the pipe is not only dependent on the rigidity of the pipe, but also on the trench and the bedding. This Guide is mainly concerned with the hydraulic design and planning of sewers. Other design guidelines – such as SANS 1200[57], SANS 676[58], SANS 677[59], and SANS 10102[60] – should be consulted for more details on pipe design and installation.

K.4.4.2 Manholes

(i) Location and spacing

The maximum distance between manholes on either straight or curved alignments should be as follows:

- 100 to 150 m where the municipality concerned has power-rodding machines and other equipment capable of cleaning the longer lengths between manholes (rod length generally <80 m). This should be confirmed with the municipality.
- 100 m where the municipality concerned has only hand-operated rodding equipment. The municipality's guidelines should be referred to for details regarding spacing.
- This distance must be decreased on steep grades so that the pressure head on any part of the sewer does not exceed 6 m under blockage conditions.
- On collector sewers, and especially outfall sewers, the distance between manholes may be increased.

Note: Consider the costs involved in acquiring power-cleaning equipment in order to permit a greater manhole spacing, especially in areas prone to theft and vandalism that can lead to blockages and higher maintenance cost.

Manholes should also be placed in the following circumstances:

- At all junction points where main sewers meet (not every plot connection)
- At all changes of gradient
- At all changes in direction – except in the case of curved alignment and at the top of shallow drops
- Where there is a change in pipe diameter in outfalls (pipe soffits must be equal)
- Where two or more sewer lines connect
- At positions on steep grades (1:10 or steeper), to prevent backpressure in house gullies under blockage conditions
- At the higher end of all sections that serve more than three dwelling units and that are longer than 50 m
- At least one manhole within the road reserve where sewers cross a road

Where manholes have to be constructed within an area that would be inundated by a flood of 50 years' recurrence interval, they should be raised so that the covers are above this flood level.

It is advisable to place gullies away from where stormwater flows or collects. The number of gullies should be limited, if practical.

Where the sewer and water lines are to be installed in the same trench, sewer manholes should be positioned to allow for a minimum clearance distance of 500 mm between the outside of any manhole and the water pipeline.

(ii) Types

Six types of standard manholes are presented in Table K.19.

Table K.19: Manhole types	
Type	Description
Types I, MA and MB	These manholes are used in conjunction with sewer pipes with a diameter of 300 mm and smaller.
Type III	This manhole is similar to types I, MA and MB, but is constructed of precast concrete sections.
Type Z	This manhole is used in conjunction with pipe diameters from 375 mm up to and including 600 mm and is constructed from cast-in-situ class 20/19 concrete. The roof slab is provided with a 225 mm diameter hole for the fitting of a ventilation pipe.
Type Y	This manhole is similar to type Z, except that it is used on pipelines exceeding a diameter of 600 mm.

As types Y and Z manholes are not used at pipeline junctions, special manholes should be used. Relevant design standards should be sought for non-standard structures such as manholes for in-situ sewers, metering structures, and inlet and outlet structures.

(iii) Sizes

The minimum internal dimensions of manhole chambers and shafts are shown in Table K.20.

Table K.20: Minimum internal dimensions of manhole chambers and shafts		
Shape	Chamber	Shaft
Circular	1 000 mm	750 mm
Rectangular	910 mm	610 mm

The minimum height should be 2 m from the soffit of the main through the pipe to the soffit of the manhole chamber roof slab, before any reduction in size is permitted. Manholes deeper than 3 m should be a minimum of 1.5 m in diameter.

(iv) Benching

An area of benching should be provided in each manhole so that a person can stand easily, comfortably and without danger, while working in the manhole. Channels and benching should be shaped correctly and carefully to minimise any possible turbulence.

Manhole benching should have a grade not steeper than a ratio of 1:5, nor flatter than 1:25, and should be battered back equally from each side of the manhole channels such that the opening at the level of the pipe soffits has a width of 1.2 d, where d is the nominal pipe diameter.

The in-situ casting for channelling and benching in manholes and adjoining culverts should be rendered in 25 mm thick granolithic concrete and finished smooth and true with a steel trowel and rounded at corners and edges. The benching should be taken to 25 mm above the highest pipe soffit.

(v) Pipes entering a manhole

After the manhole foundation slab has been cast, the semi-circular channels and fittings suitable for the type of pipe laid should be placed in position and embedded in the concrete benching. The sockets of channels and the space between two abutting channels should be filled with a 1:1 cement : sand mortar mix, well worked in, and all joints should be neatly finished off.

Pipes entering manholes should be cast into position in the benching to ensure a watertight joint between the pipe and the manhole. Caulking should only be allowed where a pipe is built into an existing manhole.

The pipes built into manholes, or culverts adjoining large manholes, should be encased in concrete after the walls have been completed, and the sewer should be jointed in such a way that the pipes produce a flexible joint on each side of each manhole or culvert.

(vi) Design of manholes

All manholes, including the connection between manhole and sewer, should be designed in accordance with the requirements of industry standards, such as *SABS 1200 LD Sewers, Standardized Specification for Civil Engineering Construction*.[61] Where manholes are of cast-in-situ concrete, chambers, slabs and shafts should be structurally designed to have a strength equivalent to a brick or precast concrete manhole.

For manholes located in road reserves, spacer rings or a few courses of brickwork should be allowed for between the manhole roof slab and the cover frame to facilitate minor adjustments in the level of the manhole cover. Adjustable manhole frames may also be used.

Heavy-load type manholes should be used in trafficked areas and medium-load type manholes everywhere else.

(vii) Steep drops

Steep drops should be avoided wherever possible. Where a steep drop is unavoidable (e.g. to connect two sewers at different levels), use should be made of a steep, short length of pipe connected to the higher sewer by one or more 22.5 degree bends and to a manhole on the lower sewer also by one or more 22.5 degree bends, as shown in Figure K.26.

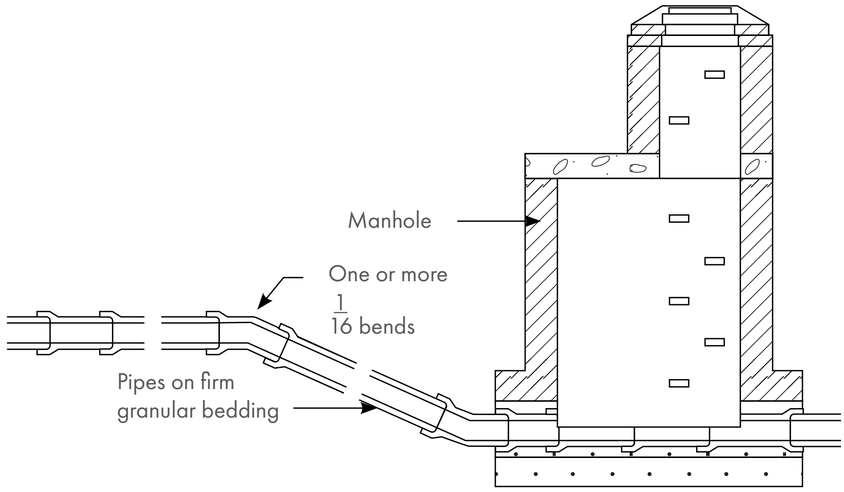


Figure K.26: Steep drops in sewers

(viii) Backdrop manholes

A backdrop and/or ramp junction manhole should not be used in sewer systems. Where flows and economy considerations (e.g. trench depth) become significant, the alternative of two closely spaced manholes or lamp holes, or a combination of these, is the prescribed option.

(ix) Elevation drop through manhole

The minimum slope in any manhole from the inlet pipe to the outlet pipe in a straight line (elevation drop through the manhole) is the greater of

- 50 – 80 mm, or
- the slope of the inlet pipe, or
- the slope of the outlet pipe.

This drop through the manhole is to minimise energy (hydraulic) losses. Where there is a change of direction in a manhole, the minimum height difference between inlet and outlet pipes should be increased to allow for the loss of energy around the bend. Table K. 21 gives an indication of the fall in manholes (mm), for various bends and pipe sizes up to 300 mm.

Table K.21: Fall in manholes for various bends and pipe sizes

Diameter (mm)		150				250				300			
Angle (degree)		0	22.5	45	90	0	22.5	45	90	0	22.5	45	90
Gradient	1:20	60	79	98	136	60	79	135	210	60	108	156	251
	1:30	40	53	65	90	40	65	90	140	40	72	104	168
	1:40	30	39	49	68	30	49	67	105	30	54	78	125
	1:50	24	32	39	54	24	39	54	84	24	43	62	100
	1:60	20	26	33	45	20	32	45	70	20	36	52	84
	1:70	17	22	28	39	17	28	38	60	17	31	44	72
	1:80	15	20	24	34	15	24	34	52	15	27	39	63

For larger diameter pipes (>300 mm), the standard energy equation should be used for calculating the drop. Also, for gradients steeper than 1:15, the actual drop through the manhole, plus 25 mm, must be provided.

$$h_b = \frac{k_b v_f^2}{2g}$$

Where:

k_b = Energy loss coefficient (see Table K.22)
v_f = Velocity in pipe at full-flow conditions (m/s)
h_b = Energy loss (m)

Table K.22: Energy loss coefficients

Angle (degree)	Energy loss coefficient (k_b)
0 – 22.5	0 – 0.1
22.5 – 45	0.1 – 0.2
45 – 90	0.2 – 0.4

(x) Turbulence and odour prevention

Turbulence at junctions and in manholes may cause bad odours, which must be reduced to a minimum by doing the following:

- Limit the number of connections to interceptor sewers.
- Avoid situations that may lead to hydraulic jumps, such as ramps and sudden changes from steep to flat grades – where one grade is five or more times flatter than the other grade in the mains.
- Shape channels and benching in manholes carefully and correctly.

(xi) Watertightness

Provide for the sealing of manholes for watertightness with an approved sealant to prevent ingress of stormwater. Joints should be caulked with a waterproofing compound. The outside of the joint should be wrapped with a sealing tape.

(xii) Vandalism and theft

Consider the risk of vandalism and theft when selecting the manhole cover material and lid type, to reduce or eliminate the risk of manhole lids being removed or damaged.

K.4.4.3 Sewer connections

(i) Plot connections

The following should be considered when designing plot connections:

- Connections should be a minimum of 100 mm internal diameter.
- It is acceptable to have direct connections to 150 mm pipes in residential areas. Connections to sewers of more than 150 mm diameter are only allowed through manholes. It is advisable to have industrial connections directly into a manhole on the sewer main. An inspection chamber should be constructed on the property boundary for commercial park developments upstream of the manhole where the connection is made.
- Unused plot connections should be terminated with a suitable watertight stopper on the boundary of the plot, or the boundary of the sewer servitude, whichever is applicable.
- Locate the connecting sewer deep enough to drain the full area of the plot portion on which building construction is permitted (minimum of 80% of the total plot area).
- The sewer connection should ideally be provided at the lowest suitable point on the plot.
- Consult the municipality for guidance with multi-plot connections.

Exceptions to the above-mentioned considerations are the following:

- In special residential areas, where a plot extends for a distance of more than 50 m from the boundary where the connecting sewer is laid, provision needs only be made to drain the area of the plot within 50 m of this boundary.
- School sites should be carefully evaluated with regard to the position, diameter and depth of the connection(s) provided.
- Where detailed development proposals are submitted for subdivided plots as group schemes, one connecting sewer may be provided to serve such group of plots.

(ii) Road crossings

House connections crossing a road should be avoided. Where it is possible to connect two plots at a time via a single-sewer road crossing (which is the preferable option), the two plots should connect via a lamp hole onto the 160 mm diameter sewer road crossing.

Where plots have to be connected to a sewer on the opposite side of a street, consideration should be given to the economics of providing 100 mm diameter sewer branches across the road to serve the connecting sewers from two or more plots.

(iii) Depth and cover

The recommended minimum values of cover to the outside of the pipe barrel for connecting sewers are as follows:

- Servitudes: 600 – 800 mm
- Road reserves: 1 000 – 1 100 mm

(iv) Invert level

In the design of sewers, consider the final finished levels of carriageways, sidewalks and vehicle entrances to properties, and the depth of sewer inverts below finished sidewalk levels, particularly for steep crossfalls. The invert levels indicated at a manhole location should be the levels projected at the theoretical centre of the manhole by the invert grade lines of the pipes entering and leaving such manhole. In cases where branch lines with smaller diameters enter a manhole, the soffit levels of these branch lines should match those of the main branch line. However, in areas where pipes are laid to minimum grades, this practice may need to be relaxed. The slope of the manhole channel should be as required to join the invert levels of the pipes entering and leaving the manhole without allowing any additional fall through the manhole chamber.

When designing the invert depth of the main sewer to ensure that all the plots can drain to it, the fall required from ground level at the head of the house drain to the invert of the main sewer at the point where the connecting sewer joins the main sewer should be taken as the sum of the following components:

- 400 - 450 mm to allow for a minimum cover of 300 mm at the head of the house drain, plus 100 - 150 mm for the diameter and thickness of the house drain
- The fall required to accommodate the length of the house drain and the connecting sewer, assuming a minimum grade of 1:60 and taking into account the configuration of the plot and the probable route and location of the house drains
- The diameter of the main sewer

In the case of very flat terrain, and where the house drains may be laid as an integral part of the engineering services, flatter minimum grades than 1:60 for the house drains may be considered. This relaxation could also be applied to isolated plots that are difficult to connect, or the ground in such plots could be filled to provide minimum cover to the drains.

Except where the depth of the existing infrastructure dictates otherwise (depending on the invert level of the existing sewer), the minimum depth to the invert of a sewer connection is as follows:

- Mid-block: 1.2 m
- Road reserve: 1.5 m

The depth of interceptor sewers should be at least 0.6 m deeper than calculated theoretically, starting from a high point on the sewer. The highest possible invert level of the municipal sewer (HILS) at the plot connection point may be calculated as follows:

$$HILS = LGL - \frac{0.3}{60} - L - Ø$$

Where:

LGL = Minimum ground level on the plot (to enable drainage of even the lowest point of the plot)
0.3 = Minimum cover required at the head of the plot connection
L = Length of the plot connection
$Ø$ = Diameter of municipal sewer (to enable soffit-to-soffit connection)

The following formula and Figure K.27 can also be used to calculate the depth of the invert of the sewer-house connection:

$$\text{Invert level at B} = ZA - 0.4 - \frac{(L1 + L2)}{60} - 0.5$$

Where:

ZA	= Ground level at A
ZB	= Ground level at B
L1 and *L2*	= Maximum length of private sewer (house connections)
DB	= Depth of sewer at point B
0.4 m	= The minimum depth at the extremity of any house drain (0.3 m cover and 0.1 m is the diameter of a drainpipe)
0.5 m	= 0.5 m for the junction at the municipal sewer
1/60	= 1:60 is the minimum gradient of a house connection

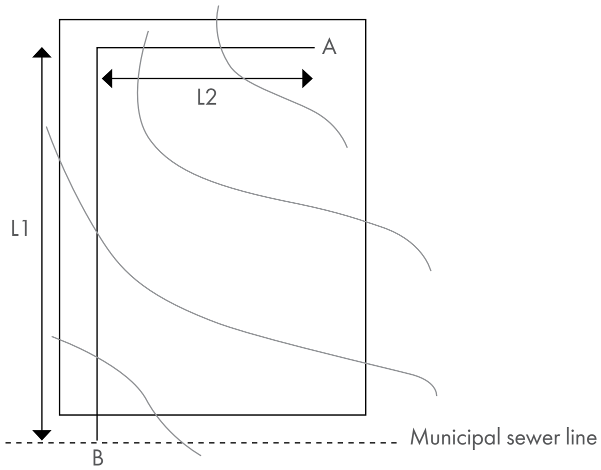


Figure K.27: Diagram of the depth of the invert of the sewer-house connection

(v) Junction with the main sewer

A plain 45 degree junction should be used at the point where the connecting sewer joins the main sewer, with the junction leg pointing upwards at an angle. Saddles should not be permitted during initial construction.

The junction with an interceptor sewer should preferably be soffit-to-soffit. Due consideration should be given to the hydraulic energy lines when designing junctions. A 0.5 m invert depth should be allowed for the junction at the municipal sewer.

K.4.4.4 Pump stations

(i) Location and siting

The location and siting of pump stations should meet the following requirments:

- Result in minimum impact (incidence and effect) on the environment (pollution), especially regarding wastewater overflows
- Minimise any community impact and be as far as possible from any future/present residential areas
- Minimise inconvenience to those using it, as well as those operating and maintaining it

- Minimise impact in the event of something going wrong
- Be outside the 1:50-year flood line

(ii) Safety precautions

Safety precautions in accordance with the relevant legislation and by-laws should be incorporated in the design of all pump stations, and in particular in the precautions referred to in the Factories, Machinery and Building Work Act, 1941 and the Occupational Health and Safety Act, 1993.

(iii) General physical design considerations for pump stations

The following aspects should be taken into account in the design of a pump station:

- Pumps (impeller and casing ports) should be designed to allow solids to pass through and be non-clogging and non-ragging. The impellers should be able to pass solids of up to 75 mm in diameter. Impeller size should be chosen based on the expected requirement of solids handling. Some discharge port sizes and particle sizes are provided in Table K.23.

Table K.23: Discharge port sizes and particle sizes

Size of discharge port	Particle size
Up to 100 mm	75 mm
150 – 300 mm	100 mm
300 mm +	150 mm

- Gate valves should be provided for isolation and maintenance purposes
- Non-return valves should be provided on the delivery pipework
- Drainage of water within the pump station needs to be accommodated
- The pump station should be readily accessible during all weather conditions and have adequate space for maintenance and operation (turning and working space)
- The pump station should be fenced for protection against theft and for the sake of public safety
- Opportunity to service, remove and replace all major equipment (pumps, motors, electrical panels, valve and surge control components) must be considered in the design
- Appropriate design measures should be taken to control noise and odour
- Adequate protection measures should, where necessary, be provided at the inlets to pump stations for the protection of the pumping equipment against large solids in the effluent
- Re-priming of pumps should be considered in the design of pump stations

(iv) Sump

The following aspects should be taken into account in the design of a pump sump:

- Equipment and fixtures in the sump should be corrosion proof (stainless steel, unless otherwise specified and approved).
- Sumps should be designed to minimise solid build-up and be self-cleaning. Trench- or hopper-style sumps should be used (with side slopes of between 45 degree and 60 degree or steeper), sloping to the inlet of the

pumps. Lower angles may be used if there is strong flow. Maintenance and cleaning procedures should be accommodated in the design to remove any solids that build up in the sump.

- Care should be taken in the design of pump stations to avoid flooding of the dry well and/or electrical installations by stormwater or infiltration.
- Adequate protection, where necessary, in the form of screens or metal baskets, should be provided at the inlets to pump stations for the protection of the pumping equipment.
- The sump should be well-ventilated and adhere to relevant safety legislation to ensure the safety of personnel in the presence of dangerous gas formation.
- The sump should be designed to avoid air entrainment and low local velocities.

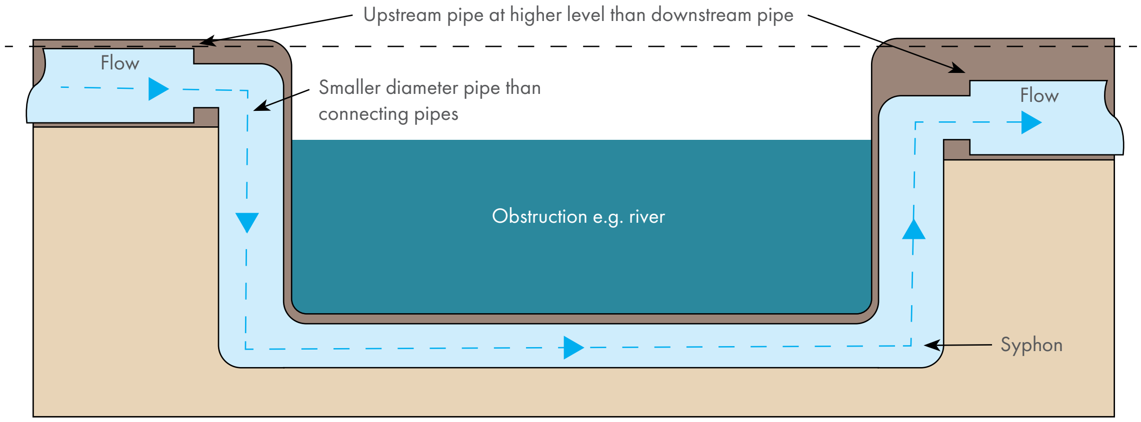
(v) Automated control in pump stations

Sewer pump stations should be fitted with automatic pump controls. At a given water level, the first pump should be activated, and if the water level rises higher, the other pumps should be activated one by one. In cases where the water level rises extremely high, the standby pump should also be activated. At a predetermined low water level, all pumps must be switched off.

K.4.4.5 Syphons

Syphons, also called sag or inverted syphons, are designed to carry flow across an obstruction (road, river, etc.) where it cannot be achieved by a sewer placed at a continuous grade. Enough pressure head must be available before and after the obstruction.

The individual pressurised pipes or conduits comprising of the syphon are normally smaller in diameter than the gravity system, resulting in higher velocities. The higher velocity serves to keep heavier solids in suspension and prevents deposition of solids.



Adapted from http://www.kingcounty.gov [62]

Figure K.28: Example of a syphon system

Syphons should be constructed with multiple pipes to match the pipes in active use with the actual wastewater being conveyed. Syphons should be designed to have three barrels and need to be full flowing to be able to operate. The three pipes should be designed as follows:

- One full-flowing pipe to be able to convey the ADDWF (minimum flow)
- Two full-flowing pipes to be able to convey ADDWF up to the PDDWF (average flow)
- Three full-flowing pipes to be able to convey the PWWF (above-average flow)

The velocity in each of the syphon pipes should be more than 0.9 m/s. The velocity in the syphon is dependent on the length of the syphon and should be as follows:

- A short syphon (<70 m) should have a velocity of ≤1 m/s
- A syphon longer than 70 m and with concrete transition structures at the inlet should have a velocity of 3 m/s

Consider the following when designing a syphon:

- The minimum self-cleansing velocity in the syphon should be obtained during ADDWF, or at least once a day during PDDWF (see Table K.24).
- The velocities in the syphon should range between 1 m/s and 3 m/s, dependent on the available head, economic considerations and the length of the syphon.
- The syphon should not have sharp bends (vertical or horizontal), changes in diameter or be too steep in gradient in the rising leg so as to ensure self-cleaning and not to complicate the removal of heavy solids.
- Hydraulic capacity of the syphon should never be lower than an upstream sewer system.
- The minimum diameter of a syphon conduit should be 150 mm.
- The friction loss through the barrel should be determined by the design velocity, and additional losses due to side-overflow weirs and directional changes (bends) should also be taken into account. The bend losses are a function of the velocity head, deflection angle, syphon diameter and radius of the bend curvature.
- As a safety factor, 10% should be added to the head losses calculated.
- Blowback should be taken into account in the design, as it can occur where free flow is at the entrance or in long syphons, as the air becomes entrapped.
- Backwater should be taken into account where the losses in the syphon are greater than the difference in the upstream and downstream water level.

The minimum self-cleansing velocities that need to be achieved for a general medium sediment load (50 mg/L) are given in Table K.24. The length of the syphon should also be taken into account (as given by the criteria above).

Table K.24: Minimum self-cleansing velocities for syphons

Internal pipe diameter (mm)	Minimum self-cleansing velocity for a sediment load of 50 mg/L
150	0.68
225	0.86
300	1.02
375	1.17
500	1.39
750	1.78
1 000	2.12

Table K.24: Minimum self-cleansing velocities for syphons	
Internal pipe diameter (mm)	Minimum self-cleansing velocity for a sediment load of 50 mg/L
1 250	2.43
1 500	2.72
1 750	2.99
2 000	3.25

To make maintenance easier, the following should be considered during the design:

- Provision of air jumpers for hydrogen sulphide control.
- Provision of acid-resistant lining on inlet and outlet structures.
- Provision of adequate working space inside the inlet and outlet structures for cleaning the pipe barrels. Verify the required space for electrical cleaning equipment.
- Provision of a cleanout point at the low point of the syphon to enable complete draining (if feasible). Alternatively, a sump at the inlet end of the syphon can be provided to allow draining of the syphon before cleaning and inspection.
- Pressure-type manholes and covers should be considered when crossing streams so as to prevent river water from flowing into the structures.

K.4.4.6 Special structures

Special structures that can be used in the design of sewer systems, include the following:

- **Diversions** - Diversion structures, or overflow structures, are required where the flow is diverted from one sewer to another. The diversion can be from one interceptor to another or to a relief sewer.
- **Junctions** - Junction structures are required when one or more branch sewers join or enter a main sewer and at diversion structures. For large sewers, junctions are usually built in cast-in-place reinforced concrete chambers provided with access points.
- **Grit traps** - Grit traps operate passively by removing heavy entrained matter from the sewage, reducing the velocity and allowing settling to occur. These traps need to be regularly cleaned to ensure optimal operation.
- **Silt traps** - Silt traps are designed to trap sand and grit. This is usually achieved by reducing the flow velocity and allowing enough time/distance for the particles to settle and remain in the trap. Depending on the anticipated volume of silt transported in the sewer system, the sizing of the settling bay will in turn determine the number of times it needs to be emptied.
- **Ventilation structures** - Ventilation structures are required when force draft ventilation is necessary. An air blower can be used at ventilation stations, although it is not always required. In the case of a syphon, consider an airline jumper that connects the inlet and outlet structures. At pump stations or treatment plants, an air blower is usually provided. The fan belt will need to be replaced from time to time and the air fan bearing will require regular lubrication.
- **Lamp holes** - Lamp holes are the openings constructed on the straight sewer lines between two manholes that are far apart and that permit the insertion of a lamp into the sewer to detect obstructions (if any) inside the sewers from the next manhole. Lamp holes are not constructed as often any more, due to more specialised equipment such as CCTV being available for inspecting sewers.
- **Flow-gauging structures** - Electromagnetic flow meters, flumes and weirs are used to measure sewage flow. Flow measuring also aids in design and monitoring.

K.4.5 Design of wastewater treatment infrastructure

K.4.5.1 Activated sludge and biofiltration treatment systems

The design of activated sludge and biofiltration treatment systems requires expertise and experience. The design aspects and considerations are dependent on the specific inflow characteristics, site conditions and treatment requirements.

K.4.5.2 Pond systems

Although pond systems are regarded as being comparatively less sophisticated than other purification systems, they nevertheless require proper planning, application, design, construction, operation and maintenance. Pond systems use a series of human-made basins in the treatment of sewage. They rely on the natural process to remove suspended solids, soluble organic matter, pathogens and nutrients (nitrogen). Stabilisation or oxidation ponds are classified according to the nature of the biological activity taking place:

- **Anaerobic ponds** (where the ponds are wholly anaerobic) – these are generally the first ponds in a series of ponds where incoming sewage settles and digests, generally at substantial depth.
- **Facultative ponds** (where both anaerobic and aerobic conditions exist) – aerobic conditions are encountered in the upper layer of the ponds and anaerobic conditions exist toward the bottom.
- **Aerobic or maturation ponds** – these ponds are generally shallow and are used mainly for final COD removal and disinfection (which is more effective at shallow depth).

Pond systems could include any combination of the pond types listed. The ponds are always positioned in a sequence of increasing oxygen level.

Both facultative and aerobic ponds derive substantial benefit from high algae concentration levels, as the algae produce large quantities of oxygen in the nutrient-rich water that is used for COD breakdown. As a result of the algal activity, the oxygen levels is generally higher than only allowed for by re-aeration through the surface. The breakdown of COD in turn supplies high levels of CO_2, which encourages photosynthesis by the algal population. The effluent discharged from pond systems can in some cases be used for irrigation. Irrigation water quality requirements are prescribed in the General Authorisations in terms of the National Water Act. These requirements are fairly relaxed up to a daily discharge of 500 m^3/d, whereafter the requirements exceed those under the General Authorisation for discharge to a water resource. Advanced and augmented pond technologies have to be considered for treatment facilities discharging more than 500 m^3/d.

The Water Institute of South Africa (WISA) published the *Manual on the design of Small Sewage Treatment Works*[63] that can be used as an initial guide to the design of pond systems and the WRC published *Wastewater treatment technologies – a basic guide.*[64] More detailed guidance is provided in the following international documents:

- *Waste stabilisation ponds*[65]
- *ISO 16075-1:2015(en) Guidelines for treated wastewater use for irrigation projects*[66]
- *Guidelines for the safe use of wastewater, excreta and greywater – Volume 1: Policy and Regulatory aspects*[67]
- *Guidelines for the safe use of wastewater, excreta and greywater – Volume 2: Wastewater use in agriculture*[68]
- *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture*[69]

K.4.5.3 Package purification plants

Package plants are generally delivered to site by suppliers as a complete unit and generally the design is based on the supplier's proprietary designs. The design and selection of package plants require specialised knowledge and experience. Authorities can consult *Package plants for the treatment of domestic wastewater*[70] as a guide when authorising and subsequently inspecting package plants. Package plant suppliers and owners also use the guideline to understand their roles and responsibilities regarding the authorisation, operation, maintenance, monitoring, and reporting on these plants.

K.4.6 Design of greywater management systems

K.4.6.1 Volumes

The per capita volume of greywater generated depends on the water use. The water use is to a large extent dependent on the level of water supply and the type of sanitation facility used. Local figures of greywater generation should be obtained. Typical figures are given in Table K.25.

Table K.25: Greywater generation

Available water supply and sanitation	Greywater generation – litres (person/day)
Standpipes; hand-washing at toilets	20 – 30
On-site single tap (yard connection); hand-washing at toilets	30 – 60
Indoor taps; hand-washing at toilets	Dependent on water demand patterns

K.4.6.2 Disposal

Given the value of greywater as a possible water resource (see **Section J**), disposal of greywater should not be the first action considered. In the case of disposal being the appropriate option for greywater, the type of disposal system will depend on various factors, including the availability of land; the volume of greywater generated per day; the risk of groundwater pollution; the availability of open drains; the possibilities of ponding; and the permeability of the soil. Some disposal options for greywater are listed and discussed below.

(i) Casual tipping

Casual tipping in the yard can be tolerated, provided the soil has good permeability and is not continually moist. Good soil drainage and a low population density can accommodate this practice. Where casual tipping takes place under adverse conditions, it may result in ponding and/or muddy conditions, with negative health effects. Excessive tipping can lead to community health risks, particularly if the basic precautions regarding greywater (see **Section J**) are not adhered to. If control or monitoring cannot be implemented, it may be best to avoid casual tipping.

(ii) Garden watering (other than vegetables and fruit)

Garden watering can be tolerated provided plants are not consumed in any way, as disease transmission may occur. Any crop gardening should be done in line with *Sustainable Use of Greywater in Small Scale Agriculture and Gardens in South Africa*[71], available from the WRC.

(iii) Soakaways

A soakaway is the safest and most convenient way of disposing of greywater, as long as soil conditions permit this. Groundwater pollution is still a possibility and care should be taken to prevent it. The design of the soakaway must comply with the guidelines given in the *National Building Regulations SANS 10400.*[72] Where simple maintenance tasks are possible, the use of grease traps should be considered for kitchen wastewater.

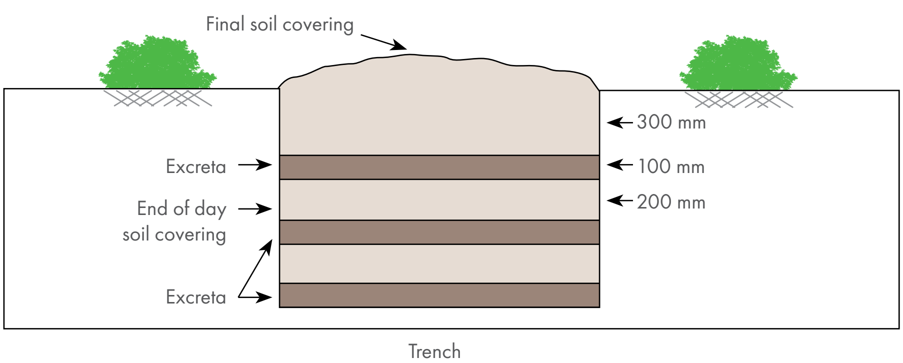
(iv) Piped systems

The disposal of greywater in piped systems is a viable option when dealing with communal washing points that generate large amounts of greywater.

K.4.7 Design of sludge disposal infrastructure

K.4.7.1 Disposal of sludge from on-site sanitation systems

On-site sanitation results in an accumulation of sludge that should be removed from the pit or tank and conveyed to some treatment or disposal facility. If the pit or tank contains fresh sewage, the sludge should be treated or disposed of in a way that will not be harmful to the environment or a threat to health. If the waste matter has been allowed to decompose to the extent that no pathogens are present any longer, the sludge can be spread on the land as compost. Pit toilet sludge can be disposed of by burial in trenches. Figure K.29 illustrates how such a burial trench should be constructed and subsequently maintained on a day-to-day basis.



Adapted from Franceys et al. 1992.[73]

Figure K.29: Disposal of pit toilet sludge in a trench

Dehydrated faecal matter from urine-diversion toilets may be safely reused as soil conditioner, or disposed of by burial, if preferred. It may also be co-composted with other organic waste.

Sludge from septic tanks, aqua privies, etc. should be disposed of in accordance with the *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 3: Requirements for the on-site and off-site disposal of sludge.*[74]

An effective refuse collection system should be in operation in high-density residential areas (see Section M). The absence of a functioning solid waste management system often leads to toilets being used for refuse disposal. This causes problems when emptying pits with a vacuum tanker. It is advisable to construct permanent pits with lined walls to prevent damage during emptying, as this could lead to the collapse of the pit walls. Note that the pit linings should make allowance for percolation of effluent into the surrounding soil (e.g. by leaving the vertical joints of a brick lining unfilled).

K.4.7.2 Composition of pit or vault contents

In a sealed tank or vault, human excreta usually separate into three distinct layers, namely a layer of floating scum, a liquid layer and a layer of sediment. Well-drained pits may have no distinct liquid layer, and therefore no floating scum layer. The scum layer is usually caused by the presence of paper, oil and grease in the tank and generally more prominent in tanks with a large number of users. The water content of pits can vary between 50% and 97%, depending on the type of sanitation system, the personal habits of the users, the permeability of the soil, and the height of the groundwater table. Cognisance should be taken of the fact that different materials used for anal cleansing will have different breakdown periods, i.e. newspaper require more time to break down than ordinary toilet paper, and in some cases will not break down at all, which could cause the pit to fill up more quickly.

K.4.7.3 Methods of emptying pits

The most suitable method of emptying a pit mechanically involves the use of a vacuum tanker, where a partial vacuum is created inside a tank and atmospheric pressure is used to force the pit contents along a hose and into the tank. Thin sludge with a low viscosity can be conveyed by immersing the nozzle below the surface of the sludge and drawing a constant flow into the tank.

The use of VIDP toilets allow the excreta to decompose into a pathogen-free, humus-rich soil, after having been stored in the sealed pit for about two years. These pits could be emptied manually, using scoops, buckets and spades to dig out the thicker sludge. Manual emptying could pose health risks and workers should wear protective gloves and clothing.

K.4.7.4 Disposal of sludge on a large scale

Unless the sludge has been allowed to decompose until no more pathogens are present, it may pose a threat to the environment, particularly where the emptying of pits and septic tanks is practised on a large scale. The design of facilities for the disposal of sludge needs careful consideration, as the area is subject to continuous wet conditions and heavy vehicle loads. Discharge speed and sludge volume dictate the equipment to be used for disposal of sludge. Cognisance should be taken of the immediate environment, as accidental discharge errors may cause serious pollution and health hazards.

Pond systems can be very effective in treating sludge from on-site sanitation systems. If the ponds treat only sludge from pit toilets, it may be necessary to add water to prevent the ponds from drying out before digestion has taken place. Sludge from on-site sanitation systems can also be treated by composting at a licensed central treatment works, using forced aeration.

K.4.8 Materials

K.4.8.1 Pipes and joints

When selecting a pipe type to use in the design of sanitation and wastewater systems, the following aspects need to be considered:

- The type of wastewater
- Corrosion, abrasion or scour conditions
- Installation and handling requirements
- The depth of the sewer
- Product specifications (smoothness, length, fittings and connections)
- Cost effectiveness (materials, installation, maintenance, and life expectancy)
- Physical characteristics (soil conditions, pipe stiffness, loading strengths, etc.)
- Municipal specifications and preferences

Pipe materials that are acceptable for sewers are listed in Table K.26.

Table K.26: Pipe materials for sewers

Diameter	Generally accepted material type
<400 mm	uPVC Heavy Duty Class 34 complying with *SANS 791 Un-plasticised poly(vinyl chloride) (PVC-U) Sewer and Drain Pipes and Pipe Fittings*[75] and fittings that comply with *SANS 1601 Structured wall pipes and fittings of un-plasticised poly(vinyl chloride) (PVC-U) for buried drainage and sewerage systems*[76] for stiffness class 400 pipes.
>400 mm	Reinforced concrete pipes containing dolomitic aggregates can be used for sewers larger than 400 mm. The pipes should have an approved sacrificial lining inside as per *SANS 677 Concrete non-pressure pipes*[77]. Other specifications are as contained in *SANS 1200 LD Sewers, Standardized Specification for Civil Engineering Construction.*[78]

Only Polyethylene (HDPE) pipes should be used in areas underlain by dolomite. Minimum allowable class PE pipe: PE80, PN6, SDR21.

All joints for rigid pipes should be of a flexible type, and rigid joints should only be used where the pipes themselves are flexible. For pipe material other than uPVC, see Table K.27.

Table K.27: Pipe material and specifications

Material	Specifications
Un-plasticised poly(vinyl chloride) structured wall pipes and fittings (PVC-U)	PVC pipes should comply with the relevant requirements of *SANS 1601 Structured wall pipes and fittings of un-plasticised poly(vinyl chloride) (PVC-U) for buried drainage and sewerage systems*[79] for stiffness Class 400 pipes and they should be fitted with approved spigot and socket joints with rubber seal rings. PVC products should be stored out of the sun and should be backfilled as soon as practicable after being laid.

Table K.27: Pipe material and specifications

Material	Specifications
Vitrified clay pipes and fittings	Vitrified clay pipes and fittings should comply with the requirements of *SANS 559 Vitrified clay sewer pipes and fittings.*[80] All pipes with a diameter of 200 mm and smaller should be plain-ended and joined with polypropylene. Pipes exceeding 200 mm in diameter should have spigot-and-socket ends with factory-applied polyurethane joints, or should be plain-ended with an approved fibreglass-type of coupling.
Reinforced concrete pipes	Reinforced concrete pipes should comply with the relevant requirements of *SANS 677 Concrete non-pressure pipes*[81] for SI type spigot-and-socket D-load pipes and should have been manufactured from the dolomitic aggregate. During the manufacturing process, each pipe should be provided with a sacrificial layer of concrete to increase the minimum cover to the reinforcement as specified in *SANS 677*[82], with the following additional thicknesses: (a) Pipes with a nominal diameter up to and including 1 500 mm – at least 15 mm; (b) Pipes with a nominal diameter of 1 800 mm and over – at least 20 mm.
Fibre-cement (FC) pipes and fittings	FC sewer pipes should comply with the relevant requirements of SANS 819 *Fibre-cement pipes, couplings and fittings for sewerage, drainage and low-pressure irrigation*[83] and should have suitable approved flexible joints. FC fittings should have a crushing strength equal to or better than that of the pipes to which they are coupled and should otherwise comply with the relevant requirements of *SANS 819*. Fibre-cement pipes and fittings should be factory-coated internally, and externally they should be covered with an approved bitumen or epoxy.
Cast-iron (CI) pipes and fittings	Cast-iron pipes and fittings should comply with the requirements of BS 78 *Specifications for Cast-iron Pipes and Special Castings for Water, Gas and Sewage*[84] and *BS 2035 Specification for cast iron flanged pipes and flanged fittings*[85] respectively. Pipes and fittings should be class A and should be factory-coated internally and externally with an approved bitumen or epoxy.

Table K.27: Pipe material and specifications	
Material	Specifications
Steel pipes and fittings	Steel pipes and fittings should be both lined and coated with a protective layer. Steel pipes should comply with the requirements of *SANS 719 Electric welded low carbon steel pipes for aqueous fluids (large bore)*[86] for grade A or B pipes, as scheduled, whereas steel fittings should comply with *BS EN 10224 Non-alloy Steel Tubes for the Conveyance of Aqueous Liquids Including Water for Human Consumption. Technical Delivery Conditions.*[87] Steel pipes should be joined by using flanges, by welding or by using flexible couplings. Gaskets for flanges should be of the full-face type, with the appropriate diameter, provided with bolt holes, and should be made of virgin rubber. They should also comply with the requirements of *BS EN 681 Elastomeric seals - Materials requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers*[88], Class WC.
Polyethylene (PE) pipes and fittings	PE pipes should comply with the relevant requirements of *SANS 4427 Plastics piping systems - Polyethylene (PE) pipes and fittings for water supply*[89] and should be one of the following: PE80 PN16 SDR9, or PE63 PN12.5 SDR9. Pipes should be joined together and to fittings by using thermos fusion carried out in accordance with the requirements of *SANS 10268-1 Welding of thermoplastics - Welding processes Part 1: Heated-tool welding.*[90]
Rubber joint rings	Rubber joint rings should comply with the relevant requirements of Part I of *SANS 974-1 Joint rings for use in water, sewer and drainage systems*[91] and should not have more than one joint. This joint should be positioned at the soffit of the pipeline.

K.4.8.2 Manholes

Manholes and chambers should be constructed as specified in *SANS 1294 Precast concrete manhole sections and components.*[92] General guidelines are as follows:

- Manhole channels should be made of precast fibre cement, even if uPVC pipes are used in reticulation.
- Manholes should be precast concrete with dolomitic aggregate or fibre-cement rings (min. 1.05 m nominal diameter).
- Manholes should be provided with access shafts and/or step irons.
- Benching in manholes should be concrete of minimum strength of 20 MPa at 28 days.
- Cast-iron manhole covers and frames should comply with the relevant requirements of *SANS 558 Cast iron surface boxes and manhole and inspection covers and frame.*[93] All surfaces not embedded in concrete should receive two coats of epoxy-tar paint.
- Precast concrete manhole covers and frames can also be used, but should be of approved manufacture and capable of carrying the same load as their cast-iron counterparts.
- Manhole frames should be bedded in a 1:3 cement: sand mortar and finished off with a reinforced concrete surround.

K.4.8.3 Bedding and backfill

Specifications, as set out in relevant industry standards, should be followed for the bedding and backfill of sewer pipes. Bedding, backfill and pipe strength should be sufficient to ensure that pipelines are not overstressed by all superimposed loading.

- All bedding material should be of selected granular material with a PI less than 6, and free from organic matter, clay or stones larger than 20 mm.
- Subsoil drains should be provided where groundwater is a problem. The designer should ensure that the design is sufficient to meet the requirements.
- Backfill material should be homogeneous and should be compacted in 150 mm layers.
- Density tests should be conducted on the backfill during installation.

K.4.8.4 Pump stations

All materials used in pump stations should be durable and suitable for use under the conditions of varying degrees of corrosion to which they will be exposed.

K.4.8.5 Concrete

Structural reinforced concrete and plain concrete below ground level and/or in contact with sewage should be designed and constructed in accordance with relevant industry design standards.[94] It is advisable to use only dolomitic aggregates for in-situ concrete. The dolomitic sand, however, may be blended with up to a maximum of 40% by mass of an approved pit sand. In-situ concrete used for the construction of pipe beddings and the concrete encasing of pipes must also conform to the relevant requirements, except that dolomitic aggregates need not be used.

K.4.8.6 Structural steelwork

All exposed steelwork should be adequately protected against corrosion.

K.4.8.7 Electrical installations

All electrical installations employed for sanitation services should comply with the Machinery and Occupational Safety Act, 1983 and with the relevant municipal electricity supply by-laws/regulations.

K.4.9 Upgrading of existing sanitation systems

The upgrading of existing sanitation systems refers to the following:

- The upgrading of existing sewerage infrastructure (to meet current and future requirements)
- The extension of the network (provide a higher level of service to users)
- Maintenance of the existing network (ensure adequate rehabilitation and maintenance)
- The upgrade of sanitation facilities (VIPs, chemical toilets, etc.)

The upgrade of existing infrastructure should be planned in terms of the priorities outlined in the relevant infrastructure and spatial development plans. It is important to implement the necessary upgrading, refurbishment and maintenance of the infrastructure at the same rate as the demand for new infrastructure.

K.4.9.1 Upgrading chemical toilets

Chemical toilets are sometimes used as a temporary solution. They are regarded as not desirable as a permanent sanitation option in a residential development. Upgrading to a more permanent system would take the form of total replacement with any improved sanitation system. The chemical toilet would be removed from the site as a unit; thus there would not be any reuse of materials.

K.4.9.2 Upgrading unventilated pit toilets

The first and most important step in upgrading ordinary pit toilets is to install a vent pipe to convert the toilet into a VIP toilet. This upgrading should be undertaken at the earliest possible opportunity. After the addition of a vent pipe, further upgrading would follow the same route as a VIP toilet (see below).

K.4.9.3 Upgrading VIP toilets

The VIP toilet provides several opportunities for upgrading. A major improvement can be attained by introducing a water seal between the user and the excreta, thus providing a level of convenience that is more acceptable to users. It may be necessary to consider the removal of liquids from the site only if problems arise with the drainage of excessive quantities of water. This can be expected when individual water connections are provided to each site. Since the pit of a VIP toilet is not watertight, it will be necessary to construct a new tank on the site for solids retention if upgrading to a settled-sewage system is required. The pit of the VIP toilet will thus become redundant. If, at the outset, the final stage of the upgrading route is known to be a conservancy tank or settled sewage system, it is preferable to begin with a sealed-tank system (such as a vault toilet, aqua privy, or on-site digester), to avoid having to construct a new tank when the upgrading takes place.

The installation of a urine-diversion pedestal is another significant improvement to a VIP toilet. The contents of the existing pit should be covered with a layer of earth. The structure may subsequently be operated as a normal urine-diversion toilet, where urine is diverted to a soakaway or collection container, and faeces are covered with ash or dry soil while drying out.

K.4.9.4 Upgrading ventilated vault toilets

The Ventilated Vault (VV) toilet is a VIP toilet that has a waterproof/sealed pit or vault. The comments on upgrading for VIP toilets also apply to this system. The upgrade option of removal of liquids from site will be different from that of the normal VIP toilet, because the VV toilet has a lined, waterproof vault that can be used. Because the VV toilet already has a waterproof tank, this system is ideal for upgrading to a settled sewage system.

K.9.4.5 Upgrading ventilated improved double pit toilets

The Ventilated Improved Double Pit (VIDP) toilet is a VIP toilet that has a double pit. The comments for the VIP also apply to the VIDP toilet.

K.4.9.6 Upgrading conservancy tank systems

A conservancy tank can be upgraded to a settled sewage system. The tank can be used to retain solids on the site.

K.4.9.7 Upgrading septic tank systems

A septic tank can be upgraded to a settled sewage system, since the outlet from the septic tank can be connected to a settled sewage system without any further alterations being necessary. Solids would be retained on the site and digested in the septic tank.

K.4.9.8 Upgrading aqua privies

The aqua privy has a rough water seal that can be greatly improved by removing the pedestal and chute and replacing them with a device such as a tipping-tray, pour-flush or low-flush pan. An aqua privy can also be upgraded to a settled sewage system, since the outlet from the aqua privy can be connected to the sewer system without any further alterations. Solids would then be retained on the site and digested in the aqua privy tank.

K.4.9.9 Upgrading settled sewage systems

No upgrading of this system is necessary, but the stand owner can implement aesthetic improvements to the superstructure. Upgrading to a conventional waterborne sewer system is not recommended due to the fact that the settled sewage system only complies with relaxed design standards, which would cause settling problems in the pipes if settling tanks are removed from the system.

Glossary, acronyms, abbreviations

Glossary

Effluent
Effluent is defined as human excreta, domestic sludge, domestic wastewater, greywater or waste resulting from the commercial or industrial use of water.

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 is excluded as a potential resource for the purpose of this Guide.

Hygiene
Hygiene is defined in the 2016 National Sanitation Policy as "personal and household practices that serve to prevent infection and keep people and environments clean, and the conditions and practices that help to maintain health and prevent the spread of diseases".

Menstrual hygiene
This shall be interpreted as the implements (including sanitation materials, soap and adequate clean water) and practices that will allow girls and women to manage their menstrual bleeding with privacy and comfort.

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.*

Sewer network
In the context of this Guide, a sewer network refers to the network of pipes that transfer sewage wastewater.

Sludge management
Sludge management entails the emptying, transport, treatment and disposal of wastewater, products of municipal wastewater treatment and effluent.

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.

Wastewater
Any water whose potable quality has been altered by domestics, industrial or other use process.

Water conservation
The minimisation of loss or waste, the care and protection of water resources and the efficient and effective use of water.[95]

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
AASHTO	American Association of State Highway and Transportation Officials
ADDWF	Average Daily Dry Weather Flow
BS	British Standard
CBD	Central Business District
CI	Cast Iron
COD	Chemical Oxygen Demand
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
FC	Fibre Cement
FAR	Floor Area Ratio
IPDWF	Instantaneous Peak Dry Weather Flow
IPWWF	Instantaneous Peak Wet Weather Flow
ISO	International Standards Organization
PDDWF	Peak Daily Dry Weather Flow
PDWF	Peak Dry Weather Flow
PF	Peak Factor
PVC	Poly Vinyl Chloride
PWWF	Peak Wet Weather Flow
SANS	South African National Standard
SuDS	Sustainable Drainage Systems
UDDT	Urine Diverting Dry Toilet

UH	Unit Hydrographs
uPVC	Un-plasticised Poly Vinyl Chloride
VIDP	Ventilated Improved Double Pit
VIP	Ventilated Improved Pit
VV	Ventilated Vault
WHO	World Health Organization
WISA	Water Institute of South Africa
WRC	Water Research Commission
WSA	Water Services Authority
WSP	Water Services Provider
WSD	Water Sensitive Design
WSUD	Water Sensitive Urban Design
WWTW	Wastewater Treatment Works

Endnotes

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[75] *SANS 791 Un-plasticised poly(vinyl chloride) (PVC-U) Sewer and Drain Pipes and Pipe Fittings* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[76] *SANS 1601 Structured wall pipes and fittings of un-plasticised poly(vinyl chloride) (PVC-U) for buried drainage and sewerage systems* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[77] *SANS 677 Concrete non-pressure pipes* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[78] *SANS 1200 LD: Sewers, Standardized Specification for Civil Engineering Construction* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[79] *SANS 1601 Structured wall pipes and fittings of un-plasticised poly(vinyl chloride) (PVC-U) for buried drainage and sewerage systems* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[80] *SANS 559 Vitrified clay sewer pipes and fittings* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[81] *SANS 677 Concrete non-pressure pipes* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[82] *SANS 677 Concrete non-pressure pipes* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[83] *SANS 819 Fibre-cement pipes, couplings and fittings for sewerage, drainage and low-pressure irrigation* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[84] BSI. 1917. *BS 78: Specifications for Cast-iron Pipes and Special Castings for Water, Gas and Sewage*. British Standards Institution, London.

[85] BSI. 1966. *BS 2035: Specification for cast iron flanged pipes and flanged fittings. Replaced By BS 4772:1988*. British Standards Institution, London.

[86] *SANS 719 Electric welded low carbon steel pipes for aqueous fluids (large bore)* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[87] BSI. 2002. *BS EN 10224: Non-alloy Steel Tubes for the Conveyance of Aqueous Liquids Including Water for Human Consumption. Technical Delivery Conditions*. British Standards Institution, London.

[88] BSI. 2002. *BS EN 681: Elastomeric seals - Materials requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers (Incorporating amendments nos. 1 and 2 and corrigendum no. 1)*. British Standards Institution, London.

[89] *SANS 4427 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/

[90] *SANS 10268-1 Welding of thermoplastics - Welding processes Part 1: Heated-tool welding* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[91] *SANS 974-1 Joint rings for use in water, sewer and drainage systems, Part I* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[92] *SANS 1294 Precast concrete manhole sections and components* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[93] *SANS 558 Cast iron surface boxes and manhole and inspection covers and frame* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[94] *SANS 1200 GA: Small Works, Standardized Specification for Civil Engineering Construction* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

[95] 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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Section L
Stormwater

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 L
Stormwater

The Neighbourhood Planning and Design Guide

Table of contents

L.1 Outline of this section

L.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 stormwater and stormwater management in this system.

Stormwater is rainwater or melted snow that runs off streets, lawns and other sites. In natural systems, the bulk (typically 85% to 90%) of rainfall is returned to the atmosphere through evapotranspiration and the remainder is filtered and ultimately replenishes aquifers (about 4% or 5%) or flows into streams and rivers either as surface runoff or shallow groundwater flow (8% to 10%). Stormwater should be regarded as a resource and it should be integrated into the settlement water cycle.

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 the sections dealing with water supply (**Section J**), sanitation (**Section K**), and transportation and road pavements (**Section I**).

L.1.2 Content and structure

This section (Section L) is structured to support effective decision-making related to the provision of stormwater management. The decision-making framework is outlined in Figure L.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 stormwater infrastructure 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 stormwater infrastructure 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 stormwater management systems that are available for consideration

Design considerations

Guidelines to assist with the design of stormwater management systems and 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 L.

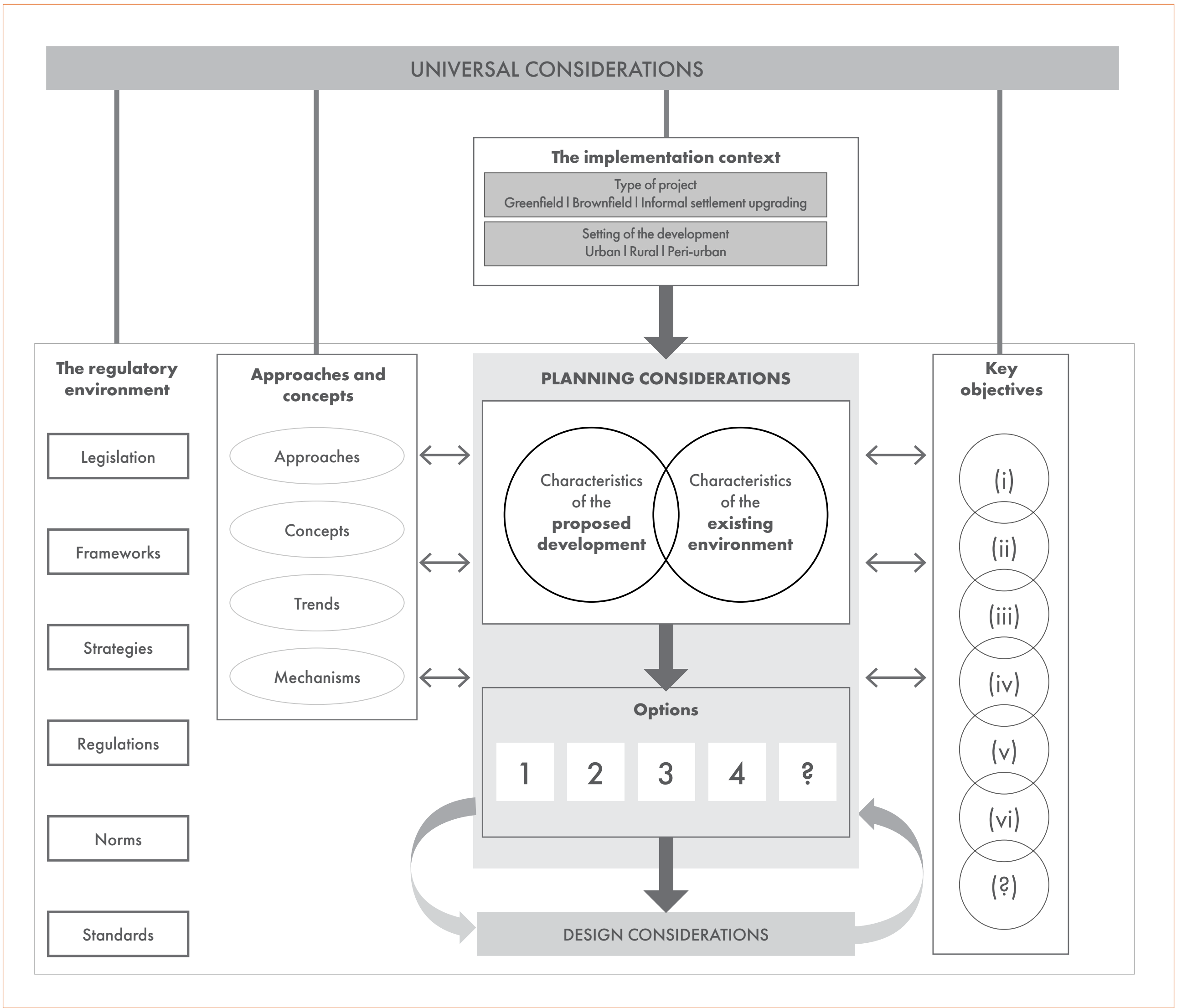


Figure L.1: A framework to assist with planning and design decisions

L.2 Universal considerations

L.2.1 The regulatory environment

A range of legislation, policies and strategies guide the management of stormwater in 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 and the management of stormwater. Below is a summary of the main acts and policies pertaining to stormwater management.

- **The National Water Services Act and the National Water Act**

The National Water Services Act (NWSA), 1997 and the National Water Act (NWA), 1998 refer specifically to the legal responsibility to insert the 100-year flood line on township plans to protect sewage treatment works, cemeteries and solid waste sites from flooding.

- **The National Environmental Management Act**

The National Environmental Management Act (NEMA), 1998 requires that all relevant factors be considered in stormwater management, including (among others) that pollution and degradation of the environment be avoided. In cases where this is not possible, the consequences must be minimised and remedied; and environmental justice must be pursued.

- **The National Framework for Sustainable Development**

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

- **The Conservation of Agricultural Resources Act**

The Conservation of Agricultural Resources Act, 1983 controls the use of natural agricultural resources to promote the conservation of the soil, water resources and vegetation, and the combatting of weeds and invader plants.

- **The National Roads Act**

The National Roads Act, 1971 regulates the construction and control of national roads, including the disposal of stormwater on a national road.

- **The Minerals Act**

The Minerals Act, 1991 and its Regulations focus on specific issues relating to the Environmental Management Programme (EMP) and implement the prescriptions of the DWS with regard to the disposal of waste and wastewater.

- **The Health Act**

The Health Act, 1977) focuses on the promotion and protection of public health in the managing of stormwater.

- **The Atmospheric Pollution Prevention Act**

The Atmospheric Pollution Prevention Act, 1965 requires the prevention of pollution of the atmosphere through specific measures aimed at the purification of effluent and the prevention (or reduction to a minimum) of any noxious or offensive constituents from such effluents getting into drains and drainage canals.

- **The Environment Conservation Act**

The Environment Conservation Act, 1989 provides for the effective protection and controlled utilisation of the environment.

- **The Second National Water Resource 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 and emphasises the need to protect fresh water ecosystems that are under threat because of pollution occurring during rain events and influx of polluted stormwater into the watercourses.

L.2.2 Key objectives

In developed areas, impervious surfaces such as pavement and roofs prevent precipitation from soaking naturally into the ground. These surfaces also reduce the opportunities for evapotranspiration, as water runs rapidly into storm drains, sewer systems and drainage ditches. This can cause downstream flooding; stream bank erosion; increased turbidity (muddiness created by stirred-up sediment) from erosion; habitat destruction; sewer overflows; infrastructure damage; and contaminated streams, rivers and coastal waters. The following objectives should guide decisions regarding the planning and design of stormwater management systems:

- Minimise the threat of flooding to the area
- Protect the receiving water bodies in the area
- Preserve biodiversity in the area
- Promote the multi-functional use of stormwater management systems (provide amenity to communities)
- Promote the use of the stormwater itself as a water resource
- Develop sustainable stormwater systems

Effective stormwater management limits negative impacts on the environment and enhances the positive impacts. It also caters for the hydraulic needs of a development while minimising the associated negative environmental impacts. The design of a sustainable stormwater management system considers all the factors that will affect the future operation and maintenance of the system. Stormwater systems should ideally be planned and designed to require minimum maintenance.

L.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 L.2.2**.

L.2.3.1 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.[2] 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.[3] 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 L.2).

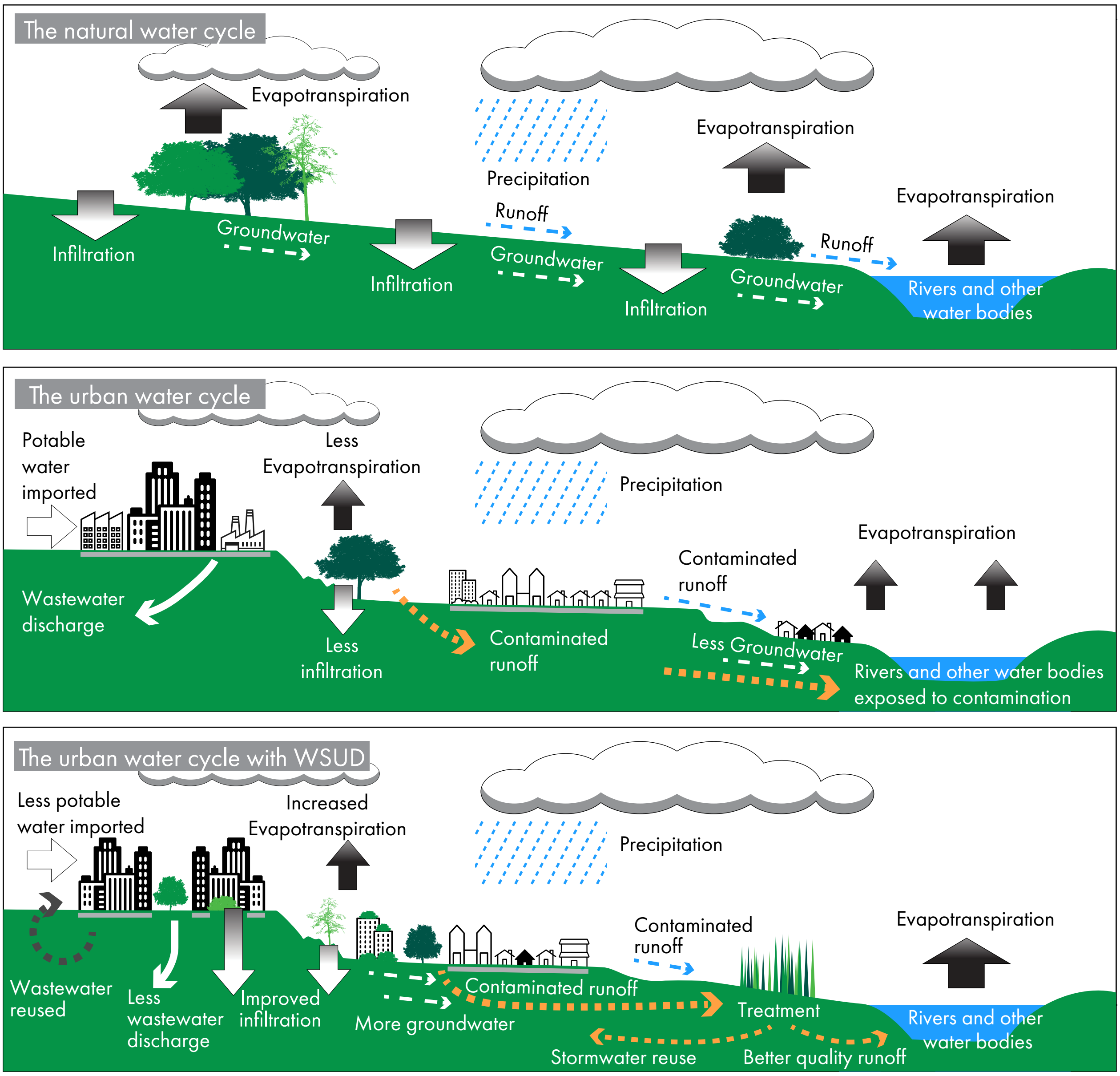


Figure L.2: The water cycle under different conditions

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:[4]

- **Sustainable Drainage Systems (SuDS).** See Section L.2.3.2 for a description.
- **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 J** (Water supply) and **Section K** (Sanitation).

L.2.3.2 Sustainable Drainage Systems

Sustainable Drainage Systems (SuDS) constitute an approach towards 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 and wetlands. 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.[5]

L.2.3.3 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".[6]

L.2.3.4 Water quality

It is essential that water, which is a scarce resource, be utilised judiciously and sensibly for the benefit of all users. Certain standards of water quality (water that is 'fit for use') are required for all users – from primary domestic use to water for irrigation, stock watering, recreation, and maintaining aquatic habitats.[7] Efficiently managing the quality of stormwater would aid in utilising the resource in a sustainable manner. Harvested stormwater could be used as a water resource as long as the water quality is of an adequate standard. See **Section L.4.1.4** for water quality checks regarding the use of stormwater for sanitation, recreation or irrigation.

L.2.3.5 The dual drainage system

Traditionally, runoff from frequent (minor) storms has been carried in the urban formal drainage systems. Typically this was achieved by draining runoff from properties into the streets and then via conduits to the natural watercourses. The system was intended to accommodate frequent storms and associated runoff. Today, the value of property is of such significance that engineers need to consider not only frequent storms but the more severe storms, which can cause major damage with sometimes catastrophic consequences. The dual system incorporates a minor system for the frequent storm events and a major system for the less frequent but severe storm events. The major system may include conduits and natural or artificial channels, but would commonly also make use of the road system to convey runoff overland to suitable points of discharge. This is not very different from what has happened de facto except that formal cognisance is now given to the routing of runoff from all storms via the secondary use of roads and other facilities in the urban environment. Despite imposing inconvenience to users, the use of the road system and open spaces (such as parks and sports fields) as drainage components of the major system is considered acceptable during these severe storm events.

L.2.3.6 Stormwater harvesting and use

Stormwater harvesting is the collection, treatment, storage and use of stormwater runoff in settlements. Harvested stormwater can be used as an alternative or additional water resource for municipal water supply, e.g. sanitation system flush water, irrigation, etc. Stormwater that has been harvested is either stored on a permanent basis in a retention pond or it could be stored in detention ponds, where water is stored temporarily following a large storm. Detention ponds reduce downstream flooding.[8] Any harvested stormwater to be used as potable water needs to go through a treatment process.

L.2.3.7 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. Refer to the *Asset Management Guideline*[10] available from the DWS for more information.

Energy and stormwater management

Energy is needed in the operation of water infrastructure systems through processes related to the treatment, transfer, and discharge of stormwater. Any infrastructure for the management of stormwater that requires an external energy source should consider renewable energy as a viable power source for such infrastructure during its design life. Stormwater can also be used in the generation of electrical energy. Refer to **Section N** for guidance on the planning for electrical energy provision in neighbourhoods.

L.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 for planning and designing for stormwater management. Also refer to **Section D.2.1** (Type of development) and **Section D.2.2** (The setting of the planned development). The interdependencies between stormwater management and the various other water-related services, such as water supply (see **Section J**) and sanitation (see **Section K**) should be considered in the planning and design of stormwater management systems.

L.2.4.1 The type of development

(i) Greenfield development

When planning and designing the stormwater management of a neighbourhood as part of a greenfield development project, the following has to be considered:

- Undisturbed portions of the natural environment are often found on greenfield sites. When planning and designing stormwater management, the preservation or improvement of natural freshwater ecosystems, and the creation of additional freshwater habitats that can contribute to the availability 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.
- 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 for the proposed development and may require an upgrade to service the proposed development adequately.

(ii) Brownfield development

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

- Brownfield sites are potentially contaminated by previous industrial uses or by leftover building materials and might need environmental rehabilitation. If rehabilitation is not possible or appropriate, the contaminated land might affect the management and quality of stormwater.
- Sites for redevelopment often have built structures that may have heritage value. Identify heritage elements that need to be protected when constructing the stormwater infrastructure.
- The layout and structure of the brownfield development project should link up with existing movement patterns, as well as surrounding streets and stormwater systems.

(iii) Informal settlement upgrading

Informal settlement upgrading often involves in-situ development. This usually implies that existing houses are left in place, while the neighbourhood is upgraded – streets are aligned and widened, drainage is improved and homes are connected to the water and sanitation grids. When planning and designing a stormwater system as part of an informal settlement upgrading project, the following needs to be considered:

- Informal settlements are often isolated from the street grid. Linking up with existing stormwater networks may have a major impact on the existing system (which needs to be mitigated).
- Informal settlements grow organically and there may be layouts that seem unconventional. The stormwater system of an upgraded informal settlement must accommodate these anomalies.
- The increasing number of dwellings that are erected below the flood line in informal settlements is of concern. Appropriate interventions are required when planning and designing for stormwater management to ensure that people and dwellings are not exposed to flood hazard.

L.2.4.2 The setting of the development

(i) Rural

The rural areas of South Africa comprise a variety of settlement types, including rural villages and towns, dense rural settlements and dispersed settlements. The stormwater management systems appropriate to the setting will therefore also vary and will be dictated by a range of factors.

- 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. Stormwater management planning and design are guided by these decision makers rather than by the local municipality's planning and development policies.
- Often, rural settlements can only be accessed by dirt roads or even footpaths.[11] These roads are particularly vulnerable to degradation during rains. The organic nature of the internal street layout of rural settlements also makes it difficult to achieve optimum efficiencies.
- Due to lower population densities, the provision of stormwater management infrastructure in rural areas may sometimes require an approach that differs from that taken in cities or towns. The use of pipe or box culverts are typically minimised, and the minimum diameters are larger than for urban areas, due to higher sediment loads. Surface drainage is often more appropriate.

(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 stormwater 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 stormwater infrastructure of new developments as these peri-urban areas are likely to accommodate even 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. For instance, several SuDS measures can generally be provided at reasonable cost.

(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 stormwater management system to be provided.

L.3 Planning considerations

This section deals with the planning of stormwater management infrastructure. 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 stormwater management 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 stormwater infrastructure and services to be provided as part of a development project.

Decisions regarding stormwater management should 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.

L.3.1 Characteristics of the proposed development

Decisions regarding stormwater management 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.

L.3.1.1 The nature of the proposed development

Various factors relating to the nature of a development could influence decisions regarding stormwater management. For instance, mixed-use, mixed-income projects and projects that are primarily residential in nature would need different approaches to stormwater management. 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 stormwater management options. 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 stormwater flow, which in turn forms the basis of designing stormwater infrastructure of adequate capacity. Outfall locations, and receiving systems should be identified.
- What is the average plot size per land use category? Information on parking areas, open spaces and streets and sidewalks is critical in the planning for stormwater management. If available, the coverage of buildings is also used in calculating flow rates.
- 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)
- What is the possible drainage densification in the catchment (this refers to an increase in the ratio of conduit length : land area)? Conduit length refers to the length of the pipe or swale. This ratio is used as a measure of the reduction in effective overland flow length.
- What is the perviousness (the ability to allow water to percolate through) of the surfaces planned for the proposed development? What are the likely or planned future vegetation of the development? Pervious surfaces

and certain types of vegetation will allow stormwater to soak into the ground, while impervious surfaces and other types of vegetation (or no vegetation at all) will result in more runoff.

- What is the planned application of Water Sensitive Design measures (refer to **Section L.2.3.1**) in the proposed development? The successful implementation of these measures will have an impact on the volume of runoff in the proposed development.

> One of the most unstable periods in any development occurs during the construction phase. Stormwater runoff from sites should be collected in temporary check dams to prevent erosion. Straw bales can be positioned at kerb inlets to prevent silt entering the underground drainage systems while construction is taking place.

L.3.1.2 The residents of the area to be developed

Decisions relating to the stormwater management system 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 by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to establish the total number of people (and households) to be accommodated. Actual numbers may be higher than anticipated because the provision of services may attract more people than originally planned for.

L.3.2 Characteristics of the existing environment

The selection of any option for stormwater management is determined by the unique characteristics of the particular site. Not all options or models will be applicable or effective for all sites. The advantages and limitations of each option should be identified during the planning and design phases, taking into consideration the site-specific characteristics and the context within which the development will be located. Issues that should be considered are discussed below.

L.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the site could influence the stormwater management infrastructure to be provided.

(i) Topography

Stormwater management systems have to reduce and/or eliminate the energy generated by flowing water. The water must not be allowed to develop sufficient volume or velocity to cause harm. The topography of the project site as well as surrounding sites is therefore a key factor when making decisions regarding the provision of stormwater management infrastructure. Important issues to consider include the following:

- What are the details of the upstream catchment? Catchment characteristics (e.g. size and elevation) will inform modelling discretisation.

- What does the existing natural drainage system comprise? Stormwater systems should result in the minimum disturbance of the natural drainage pattern. Obtain updated contours and cadastral information to identify sub-catchments.
- What is the slope shape, slope gradient and slope length? Runoff volume generally increases with steepness of slope. Slope shape determines whether water is dispersed or concentrated. Slope gradients are important when planning a stormwater management system because erosion and scour as a result of stormwater should be minimised by ensuring the flow velocities are maintained below critical values.
- What are the details and sensitivity of the receiving system? Stormwater management systems that convey stormwater to bodies of water that are classified as environmentally sensitive, for recreational use, or in public spaces, should specifically be planned to minimise or eliminate pollution.

(ii) Climate

The micro- and macro-climates of the site will have an impact on the stormwater management system. It is critical to obtain relevant rainfall data to inform the modelling of the expected runoff quantity. It is also important to determine whether there is a risk of seasonal flooding, earthquakes, veld fires, tremors and landslides. For assistance with the development of actions to adapt settlements to the impacts of climate change, consult the *Green Book: Adapting South African settlements to climate change*[13].

Information on seasonal flooding is especially important when planning for a stormwater management system. The information is used to determine the flood Recurrence Interval (RI), or return period, referring to the average interval between flood events exceeding a stated benchmark. The RI is usually expressed in years and is the reciprocal of the annual probability – i.e. the flood event with an annual probability of occurrence of 2% (0.02) has an RI of 50 years. This does not imply that a flood event will necessarily occur every 50 years, but rather that over a very long period (e.g. 1 000 years) – assuming there is no climate change – there will be approximately 20 flood events of greater magnitude (1 000/20 = 50 years).

(iii) Geotechnical characteristics

Runoff varies with soil characteristics. The following information should be considered when planning a stormwater management system:

- What types of soil are present on the site? What are the permeability and infiltration capacity of these soils? Any condition that adversely affects the infiltration characteristics of the soil will increase the amount of runoff.
- Is the soil prone to erosion? Examples of highly erodible soils in South Africa include the granitic soils found in Mpumalanga and the Highveld (Kyalami system). Although erosion is a natural phenomenon, human interference with the natural environment can rapidly increase erosion. Methods for constructing safe and economic stormwater structures in dispersive clays should be carefully considered. Dispersive clays can be highly erosive and subject to damage or failure, and they can occur in any soil with high exchangeable sodium percentage (ESP) values. The testing procedures for the identification of dispersive clays are available from the South African Institute for Civil Engineers (SAICE).[14] Design guidance on erosion prevention is provided in Section L.4.2.4.
- Are there any aggressive chemicals or minerals present? Site-specific conditions will severely affect stormwater quality. For example, stormwater conveyed to public parks should not contain chemicals or contaminants that are outside of the regulated parameters for human contact or recreational use.

- Is the site part of or close to a dolomitic area? (see the text box for a discussion on development on dolomitic sites)
- Is there groundwater present? What is the height of the water table?

Development on dolomites

Development on dolomitic land is generally governed by the Dolomite Area Designation assigned to a specific portion of the land, i.e. designation D1, D2, D3 and D4 in terms of Table 1 of *Development of Dolomite Land Part 1: General principles and requirements* (SANS 1936-1):[15]

D1	Requires no precautionary measures
D2	Requires general precautionary measures, in accordance with the requirements of SANS 1936-3[16], that are intended to prevent the concentration of water into the ground
D3	Requires precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground, in accordance with the relevant requirements of SANS 1936-3
D4	Requires additional site-specific precautions

Any kind of development, including stormwater management, should be conducted in terms of the SANS 1936[17] requirements. If residential, the development should be enrolled with the National Home Builders Registration Council (NHBRC) and it should be designed and constructed in accordance with the requirements for residential buildings on dolomite as prescribed in the NHBRC *Home Building Manual.*[18] The following precautionary measures regarding the installation and maintenance of wet services on dolomite are important:

- The Responsible person(s) should compile and use a site-specific Dolomite Risk Management Plan for the site. The owner/responsible persons should be made aware of the risks involved in building on dolomite, and be informed about how to be vigilant and act pro-actively by applying sound water management principles.
- The precautionary measures as set out in *SANS 1936-3 Development of Dolomite Land – Part 3: Design and construction of buildings, structures, and infrastructure*[19] should be studied and implemented for D2 and D3 sites.
- The professional team involved should carefully consider the appropriate site-specific water precautionary measures and then ensure and finally certify that these have been implemented.
- Wet services should be laid exactly where indicated on the drawings presented to the relevant local authority and these may not be laid below structures. The contractor, or his appointed professional team, should certify that the services have been placed as indicated.

An appropriate site-specific Dolomite Stability Investigation (DSI) in terms of Section 4.1 of *SANS 1936-2 Development of Dolomite Land – Part 2: Geotechnical investigations and determinations*[20] should be conducted prior to any development on dolomitic land. This should include a thorough assessment in terms of the site-inherent hazard. Adequate data should be collected to confidently compile a zonation map for the area of interest.

(iv) Landscape and ecology

The physical features of the landscape are important when designing a stormwater management 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 type and extent of existing vegetation on the site and surrounding areas. Vegetation can affect the volume and velocity of stormwater runoff through interception (vegetation capture precipitation, resulting in evaporation rather than water falling on the ground and contributing to runoff), transpiration (vegetation draws water from the soil and releases it as water vapour) and infiltration (roots increase the infiltration of water in the ground). Vegetation is regarded as a critical element in Sustainable Drainage Systems (SuDS) (see Section L.3.3.1 for a discussion on SuDS as an option for stormwater management).
- The type of agricultural activities in the surrounding area. One of the major reasons for soil erosion that occur in many rural areas is the over-stocking of animals. Planning for stormwater management needs to take this into account.
- 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)[21].
- Endangered or protected animal and plant species on or near the site.
- Natural features that may have cultural significance.
- The prevalence of veld fires in the area.

(v) Adjacent land uses and edge conditions

Existing and likely future land use on the site and in the surrounding areas will have an impact on the planning of a stormwater management system. The impact will be related to stormwater runoff quantity (peak flow and flood volume) and stormwater runoff quality and the following should be considered:

- Peak flows and flood volumes are influenced by the surfaces of adjacent properties. It is important to obtain information on parking areas, open spaces, streets and sidewalks in the vicinity of the project site. If available, the coverage of buildings is also used in calculating flow rates.
- Where are solid waste management sites (specifically landfill sites) positioned? The location is important, as stormwater flows through these sites and may have a significant environmental impact on the ground and on adjacent or nearby surface water bodies. Such site positioning is regulated by the DWS, from whom the minimum requirements to be adhered to are available in *Minimum Requirements for Waste Disposal by Landfill*[22], *Minimum Requirements for the Handling and Disposal of Hazardous Waste*[23] and *Minimum Requirements for Monitoring at Waste Management Facilities*[24].
- Are there any cemeteries in the surrounding area? Cemeteries pose a pollution threat in that they can contaminate water resources. Microbiological and chemical pollutants (including bacteria, viruses and parasites) can travel considerable distances and remain active within the water table for long periods[25,26,27]. The potential pollution of groundwater and surface water by cemeteries requires a thorough technical evaluation. See Section G.3 for a discussion on the provision of cemeteries.

Stormwater management systems that convey stormwater to bodies of water that are classified as environmentally sensitive, for recreational use, or in public spaces, should specifically be planned to minimise or eliminate pollution.

The best way of dealing with pollution is to try and prevent the pollution at the source. Information on potential sources of pollution that may be associated with certain land uses is presented below:

Air pollution

- Sources of air pollution should be identified, as air pollution can cause acidic deposition by rain (acid rain), which may be transported through stormwater management systems and may result in acidification of freshwater ecosystems, denudation of forested and agricultural areas, corrosion of metal surfaces, and destruction of masonry structures.

Point sources of water pollution

- **Industrial pollution:** Many industrial processes use water and produce effluent that could become part of the water released into the stormwater management systems. Abattoirs, breweries, pharmaceutical companies, as well as the fishing, tanning, and fruit and vegetable industries are relevant examples.
- **Mining:** Many pollutants emanate from mining operations. The main concern for the design of stormwater systems is acid mine drainage and its associated dissolved heavy metals. Mines are required to implement the DWS standards for the separation of clean and polluted water. For guidance, refer to *Stormwater Water Management Best Practice Guidelines for Water Resources in the South African Mining Industry*[28] and *A Manual on Mine Water Treatment and Management Practices in South Africa*[29].

Non-point sources of water pollution

Non-point sources of water pollution are difficult to locate. Technologies such as infra-red aerial photography[30] can prove helpful in identifying non-point source pollution problems, for example runoff from city streets, farms, forests, mines, construction sites, and atmospheric deposition.

- **Agricultural pollution:** Poor farming practices often have a negative impact on water in the environment. Some of the observed consequences are decreasing biodiversity; overgrazing through overstocking; pollution by fertilisers, pesticides, herbicides and fungicides; soil crusting; irrigation with polluted water; excessive sediment wash-off; and dust pollution. Guidelines in terms of the sodium adsorption ratio[31] and the adjusted sodium adsorption ratio should be consulted to ensure that the water quality does not limit productivity, and that users downstream are not disadvantaged by poor agricultural land use.
- **Urban pollution:** Polluted stormwater runoff from urban catchments has a major impact on the water-receiving bodies. Sources of pollution include road wash-off, leaky and overflowing sewers, deliberate discharge of sewage into the stormwater drainage system, and illegal dumping into stormwater systems.

L.3.2.2 Available engineering infrastructure

The provision of stormwater management infrastructure may mean the extension of existing systems. The following questions should be asked:

- What existing stormwater management infrastructure is available close to the proposed development? Does the existing stormwater management infrastructure have enough capacity to handle additional runoff? Is the existing stormwater management system in working order? Are any 'as-built' records available for stormwater management systems near the proposed development?

- What are the long-term stormwater management requirements of the neighbourhood and the settlement? Is there an existing drainage master plan available?

Master planning

Master planning is predominantly concerned with the major system. The minor system is considered a supporting system for the major system. Master planning typically involves the following:

- Allocation of space for stormwater management and drainage. Runoff will make its way downhill whether a safe drainage path has been provided or not, and management interventions cannot be implemented unless there is space to do so.
- Determination of an appropriate recurrence interval of the major flood event. This is typically 1:100 years; however, consideration should be given to using the Probable Maximum Flood (PMF) or Regional Maximum Flood (RMF). Remember that flood lines may change with development – as well as with climate change.
- Determination of an appropriate recurrence interval for the minor flood events.
- Provision of overall guidelines for runoff detention requirements, pollution abatement strategies, and the powers and responsibilities of developers and authorities within the catchment area.
- Consideration of land use on flood plains and multi-use of stormwater facilities.
- Guidelines on safety and maintenance.
- Guidelines on environmental conservation.

- What are the sizes of existing pipes in the stormwater management system? The dissipation of energy of water in canals, or of water discharging from pipes or culverts must be considered when downstream erosion and scouring are possible. The size and type of an energy dissipation system will depend on the scale. The energy of water discharging from small- to medium-sized pipes can effectively be dissipated in preformed scour holes or riprap aprons. Large pipes and culverts will require more elaborate and robust energy dissipation structures. See **Section L.4.2.4** for design guidance for energy dissipation.
- Where are the water supply points on the site and in the neighbourhood? The drainage of excess water from water supply points should be given serious consideration in developing communities and rural settlements. Erosion can occur when water flows over unprotected areas. Puddles may also be formed where disease-carrying vectors (mosquitoes) can breed.
- What are the water supply sources currently available to the site? Stormwater can be considered a water source to augment the water mix. However, the harvested stormwater needs to be treated to fit the purpose of the use. Refer to **Section J.4.2** for a discussion on different water sources available for neighbourhood water supply.

Figure L.3: Excess water at a communal standpipe redirected for garden use (L) and excess water causing erosion (R)

L.3.3 Stormwater management options

To meet the key objectives of stormwater management (see Section L.2.2), the system that is selected should minimise the change in stormwater runoff from pre-development to post-development conditions for all storm durations and recurrence intervals. This section starts with a discussion of Sustainable Drainage Systems (SuDS) as an option for neighbourhood stormwater management. Options related to different elements of the stormwater system are then discussed. The issues relevant to minor and major stormwater systems (refer to Section L.2.3.5 for an explanation of the dual drainage system) conclude the section.

L.3.3.1 Sustainable Drainage Systems

Neighbourhood development projects typically replace (permeable) natural drainage surfaces with roofs, roads and paved areas, resulting not only in an increase in stormwater runoff quantity (peak flow and flood volume), but quite often also affecting stormwater runoff quality. These man-made surfaces are typically drained by conventional infrastructure (including pipes and lined channels), which is focused on minimising and eliminating local flood nuisances. SuDS promote more natural drainage, aiming to reduce downstream flooding, allow infiltration into the ground, minimise pollution, improve the quality of stormwater, reduce pollution in water bodies, and enhance biodiversity. Stormwater is not merely collected and discarded through a system of pipes and culverts, but is recognised as a valuable resource.

SuDS encourage more natural drainage through the use of a number of key processes. These processes are linked to four elementary focal points of SuDS, namely: quantity (flow and volume); quality; amenity; and biodiversity. Refer to *The South African Guidelines for Sustainable Drainage Systems*[32] for detailed descriptions of the different processes that SuDS use to promote more natural drainage.

This section starts with a discussion on the issues that have to be considered when selecting SuDS options. Then, as per *The South African Guidelines for Sustainable Drainage Systems*[33], the various SuDS options are grouped and discussed as 'source controls', 'local controls' and 'regional controls'. The SuDS options are listed in Table L.1.

Table L.1: SuDS options	
Group	**SuDS intervention**
Source controls: Stormwater runoff is managed as close to its source as possible, usually on site	• Green roofs • Rainwater harvesting • Soakaways • Permeable pavements
Local controls: Stormwater runoff is managed in the local area, typically within the road reserve	• Filter strips • Swales • Infiltration trenches • Bioretention areas • Sand filters
Regional controls: The combined stormwater from several developments is managed	• Detention ponds • Retention ponds • Constructed wetlands

(i) SuDS selection

Stormwater is managed by selecting an appropriate combination of SuDS options based on the unique characteristics of the site as well as the management objectives of the local municipality. The matrix presented in Table L.2 can assist in choosing between different SuDS options and selecting an optimal combination of interventions. Information is provided on each of the controls (source, local and regional) relating to their possible impact on stormwater quantity and quality issues. An indication is given whether the selected intervention will contribute to improved amenity and biodiversity in the area. The last three columns provide an indication whether costs (in terms of land take; capital; and operation and maintenance) related to the intervention are likely to be high, medium or low.

Table L.2: SuDS conceptual design matrix

		Quantity					Quality						Amenity		Biodiversity	Costing		
		Rainwater harvesting	Infiltration	Detention	Conveyance	Long-term storage	Sedimentation	Filtration	Adsorption	Biodegradation	Plant-uptake	Nitrification	Recreational benefits	Aesthetic enhancement	Habitat provision	Land take	Capital	Operation and maintenance
Source controls	Green roofs	S	×	P	×	×	P	P	P	P	P	P	Y	Y	Y	×	L/M	M
	Rainwater Harvesting	P	×	S	×	P	PR	×	×	×	×	×	×	×	N	L	M/H	M
	Soakaways	S	P	S	×	×	PR	P	P	P	×	×	×	×	N	×	M	L
	Permeable pavements	S	P/S	P/S	S	×	×	P	P	S	×	×	Y	Y	N	×	L/M	L
Local controls	Filter strips	×	S	S	P	×	P	P	P	P	S	S	Y	Y	Y	H	L	L
	Swales	×	S	S	P	×	S	P	P	S	S	S	×	Y	Y	M	L	M
	Infiltration trenches	S	P	S	×	×	PR	P	P	S	×	S	×	×	N	L	L/M	M
	Bio-retention areas	S	P	P/S	×	×	P	P	P	P	P	P	×	Y	Y	M	M	M
	Sand filters	S	S	P	×	×	S	P	P	S	×	×	×	×	N	L	L/M	M
Regional controls	Detention ponds	×	S	P	×	×	P	×	×	×	×	×	Y	Y	Y	H	L	L
	Retention ponds	P	S	P	×	P	S	S	S	P	P	P	Y	Y	Y	H	M	M
	Constructed wetlands	S	S	P	×	P	S	S	P	P	P	P	Y	Y	Y	H	H	L/M
		Primary process (P) Secondary process (S) Pre-treatment Required (PR) Not applicable (×)											Provides amenity/habitat (Y) Does not provide amenity/habitat (N)			High (H) Medium (M) Low (L)		

Acknowledgement: Armitage et al.[34]

Each of the control measures utilises slightly different SuDS processes, which are grouped in Figure L.4 as minimised release of pollutants (good housekeeping); source controls; local controls; and regional controls. A combination of these interventions results in a treatment train (a combination of different methods implemented in sequence or concurrently, and illustrated in Figure L.4) that should achieve the desired level of treatment. A consistent and regular maintenance plan is required for the effective operation of each stormwater control measure and they should also be inspected and maintained after large storm events.

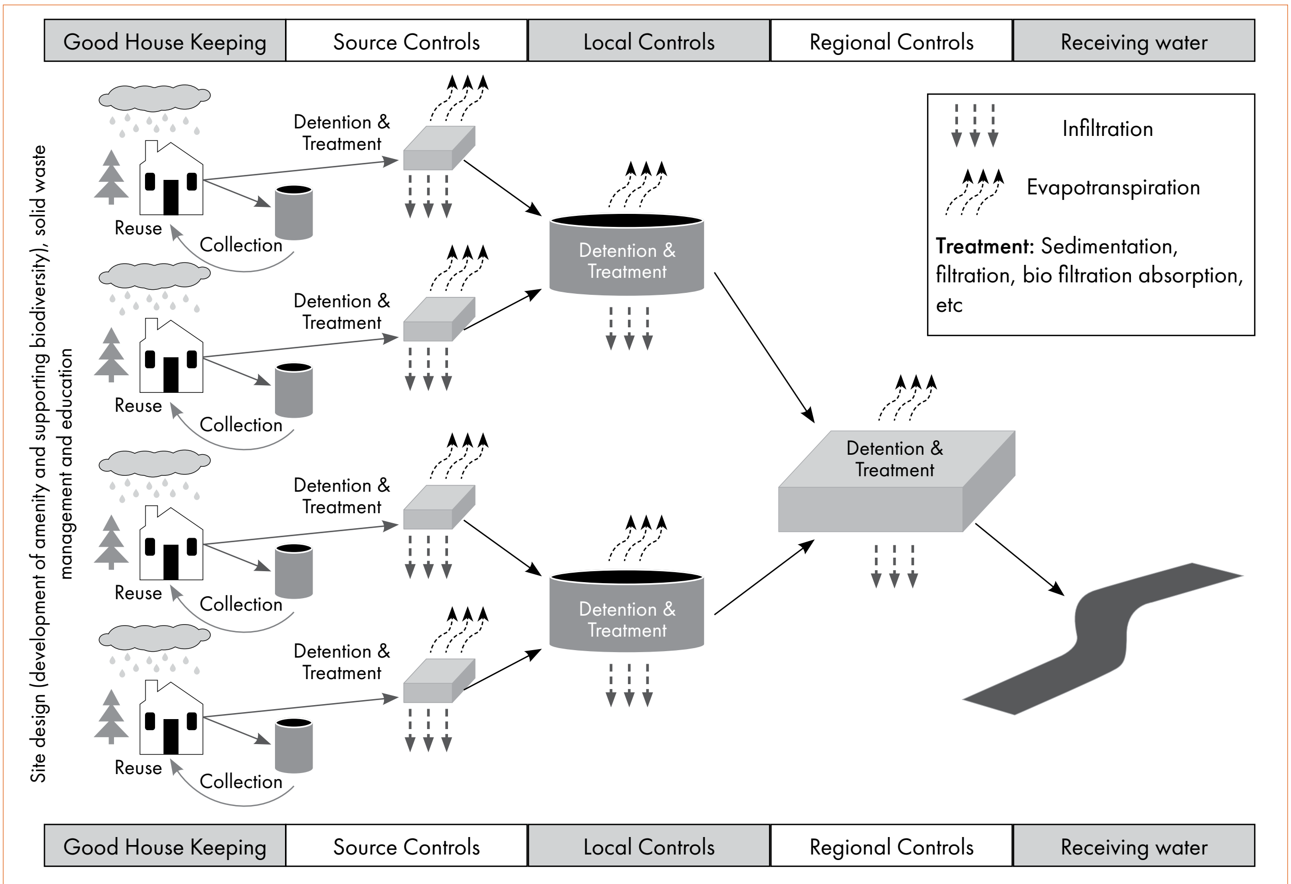


Figure L.4: SuDS treatment train schematic

Acknowledgement: Armitage et al.[35]

The increased complexity introduced by a SuDS approach to stormwater management has required the following terms to be defined:

WQV (m^3) The Water Quality Volume is the volume of water from small storm events where the focus is on treating for water quality. The storm events typically have an RI of less than one year; they are less than the 90th percentile storm, or have less than a set depth of precipitation, e.g. 25 mm in the drier areas of the country and 30 mm in the wetter areas.

ReV (m^3) Recharge Volume is the proportion of the WQV that should be infiltrated on site to make up for the reduction of natural infiltration.

CPV (m^3) The Channel Protection Volume refers to the volume and rate of flow required for management to reduce the potential for degradation in natural channels. It is usually achieved through the detention of runoff on site. The critical storm event typically has an RI of around two years.

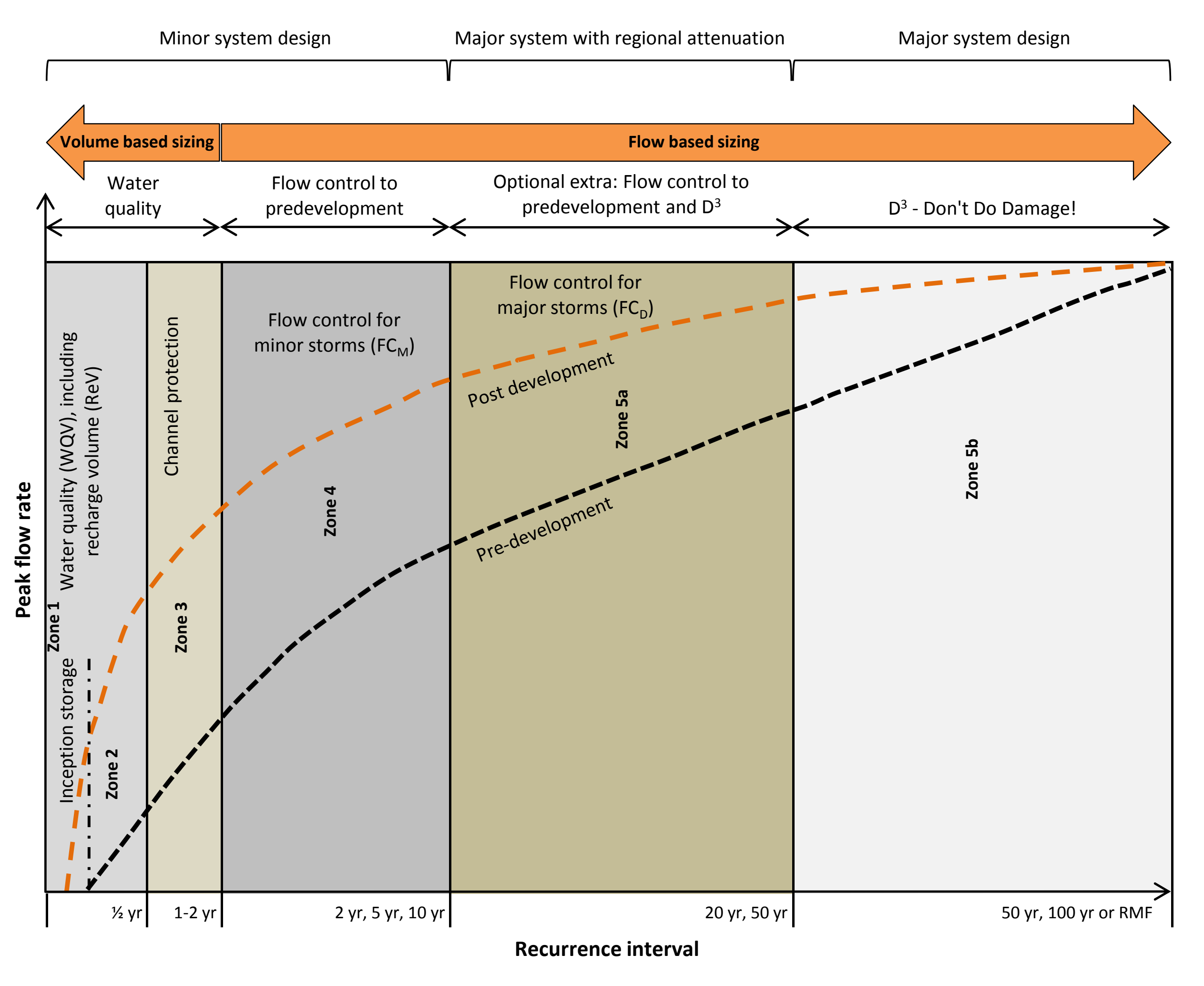
FCM (m^3/s) Flow Control (minor storms) refers to the reduction of peak flow to the pre-development scenario typically for storm events with an RI of between two and ten years, depending on the type of development.

FCD(m^3/s) Flow Control (major storms) is also required for maintaining pre-development flows and preventing damage to property and risks to life for storm events with an RI of greater than, say, ten years.

D^3 Don't Do Damage refers to the importance of ensuring that extreme storm events do not cause significant damage to property and pose significant risks to life.

Using these terms, SuDS design event criteria have been developed. The proposed design RIs are listed in Table L.3, and the range of applicability is illustrated in Figure L.5.

Table L.3: Proposed design Recurrence Intervals[36]		
RI (years)	**Objective/Component**	**Treatment**
0.25 to 0.5	Interception storage; Water Quality Volume (WQV) including Recharge Volume (ReV)	None or good housekeeping or source or local controls or combinations
0.5 to 2	Channel Protection Volume (CPV)	Source and local controls
2 to 10	Flow Control for minor storms (FC_M)	Local and regional controls
10 to 20	Flow Control for major storms (FC_D)	Roadway and regional attenuation
>20	Don't Do Damage (D^3)	Major design interventions



Acknowledgement: Adapted from Armitage et al.[37]

Figure L.5: Conceptual stormwater design framework

Figure L.5 indicates the following five distinct design 'zones' that need to be considered for SuDS design:[38]

- All precipitation is absorbed through interception storage and infiltration in Zone 1.
- As the storm intensity increases, the focus (in Zone 2) moves to the management of runoff quality and quantity.
- It is often very difficult to handle water quality issues for all but small storms; past a certain threshold the emphasis starts to move to one of channel bed protection (Zone 3).

- There is still a need to minimise inconvenience, so SuDS must give the equivalent peak overland flow protection offered by conventional systems beyond that achieved in Zones 1-3. This is covered in Zone 4.
- SuDS need to be designed for major events just like conventional systems. Zone 5 may thus be divided into two: Zone 5a where peak flows may be reduced to pre-development, and Zone 5b where the emphasis moves to minimising damage to property and potential loss of life (D3 = Don't Do Damage).

(ii) SuDS source controls

Source controls are used to manage stormwater runoff as close to its source as possible – generally within the boundaries of the property – and include green roofs and buildings; rainwater harvesting; infiltration and evapotranspiration; soakaways and permeable paving. Design guidance for these source control measures is provided in Section 4.2.1(i).

Green roofs and buildings

A green roof is a roof on which plants and vegetation can grow. The vegetated surface provides a degree of retention, attenuation, temperature insulation, and treatment of rainwater.

Rainwater harvesting

Rainwater harvesting is the direct capture of stormwater runoff, typically from roads, pavements, large buildings, rooftops, etc., for supplementary water, which can be used on site. See Section J.4.2 for a discussion on rainwater harvesting as augmentation to the water resource mix.

Infiltration and evapotranspiration

The most frequently used methods of controlling runoff frequency and volume are systems that promote infiltration and evapotranspiration. These can range in complexity from informal to semi-formal rain gardens that promote infiltration and evapotranspiration. This may incorporate a filtration medium, or structural soakaways that promote infiltration only. Bioswales promote both infiltration and evapotranspiration and provide an environment for biological processes that improve water quality, often by incorporating filtration, storage media and an underdrain system. Where possible, rain gardens or bioswales are favoured over soakaways because they can provide visual interest and habitat diversity in the landscape. These devices are scalable in that they can be used for small- to medium-sized catchments, but are most effective for controlling the runoff from more frequent events.

Soakaways

The purpose of a soakaway or French drain, is to provide temporary storage and facilitate the infiltration of stormwater into the groundwater. Storage is provided in a tank or in an excavation filled with a stone medium of high porosity.

Photo credit: Achim Hering -Wikimedia Commons (R)[39]

Figure L.6: A rainwater harvesting system (L) and permeable pavement (R)

Permeable pavements

Permeable pavements are a stormwater control measure that replaces traditional impervious paving with a permeable surface that allows stormwater to drain through into an underlying storage and drainage layer. Water is lost from the storage layer either by infiltration into the subgrade, or via a subsurface drainage system. The water may be harvested for landscape irrigation.

(iii) SuDS local controls

SuDS local controls are used to manage stormwater runoff as a second 'line of defence', typically in public areas such as road reserves and parks. SuDS local controls include detention basins; filter strips; swales; infiltration trenches; bioretention areas; and sand filters. Design guidance for these local control measures is provided in Section 4.2.1(ii).

Detention basins

Detention basins are temporary storage facilities that are ordinarily dry but store stormwater runoff for short periods of time during periods of high flow. The size will depend on the extent of the developed area. The detention basins have limited treatment capacity other than that achieved through the deposition of silt and solid waste.

Filter strips

Filter strips are maintained grassed areas of land that are used to manage shallow overland stormwater runoff through several filtration processes.

Swales

A swale is a shallow vegetated channel designed to convey stormwater, but it may also permit infiltration. The vegetation assists in filtering particulate matter and capturing nutrients.

Infiltration trenches

Infiltration trenches are excavated trenches that are filled with broken rock, coarse gravel, or commercial void-forming products (like soakaways described above).

Bioretention areas

Bioretention areas (rain gardens, bioretention cells, bioswales) are landscaped depressions typically employed to manage the runoff from the first 25 mm or so of rainfall by passing the runoff through several natural processes (filtration, adsorption, biological uptake, sedimentation, infiltration and detention). Different bioretention areas include:

- **Rain gardens:** A rain garden is a planted depression that receives stormwater runoff from impervious areas and less pervious vegetated areas such as compacted lawns, giving this water an opportunity to soak into the ground. It can be as simple as a small depression in the natural soil, or a more elaborate system containing an engineered growing medium and a gravel storage layer. Rain gardens are the simplest of all SuDS interventions and, because of their simplicity and scalability, can be among the most effective.
- **Bioretention cells:** A bioretention cell is a planted depression that receives stormwater runoff from impervious areas and less pervious vegetated areas such as compacted lawns. It drains this water away by slow surface and subsurface flow, while giving it an opportunity to soak into the ground. It is a more elaborate system than a rain garden, containing an engineered growing medium, a gravel storage layer, and a gravel drainage layer with or without an agricultural drain.
- **Bioswales:** A bioswale differs from a rain garden or a bioretention cell in that it has a linear drainage component. It differs from a conventional cell because it is constructed with selected filtration media and underdrains to improve water quality. Bioswales can serve additional purposes, for example eliminating the need to irrigate street trees.

Figure L.7: Examples of a rain garden (L) and a bioswale (R)

Photo credit: Wikimedia Commons - Rogersoh (L)[40], Chris Hamby (R)[41]

Sand filters

Sand filters normally consist of a sedimentation chamber linked to an underground filtration chamber that comprises sand or other filtration media through which stormwater runoff passes.

(iv) SuDS regional controls

SuDS regional controls are used to manage stormwater runoff as a last 'line of defence', and typically constitute large-scale intervention on municipal land. All regional facilities should be accessible by the local authority for inspection and maintenance purposes. The key management tool is water storage, which may be incorporated into the stormwater system in many ways to regulate the rate of discharge from the system, improve water quality and reduce peak flow rates. The controls may also have recreational or biodiversity functions and include detention ponds; retention ponds; and constructed wetlands. Design guidance for these regional control measures is provided in Section 4.2.1 (iii).

Detention ponds

Detention ponds or detention basins are temporary storage facilities that are ordinarily dry, but they store stormwater runoff for short periods of time during periods of high flow. These facilities can be designed to be multi-purpose, e.g. they can serve as parks or sports fields when not required for flood management. The captured stormwater runoff either infiltrates into the underlying soil layers or, more usually, is drained into the downstream watercourse at a predetermined rate.

Retention ponds

Retention ponds store water permanently. They are generally formed through the construction of a dam wall equipped with a weir outlet structure. The maximum storage capacity of retention ponds should be larger than their permanent pond volume. Stormwater flowing into the pond is mixed with the permanent pond water and released over the weir at a reduced rate. Retention ponds are frequently combined with stormwater detention facilities to provide blue/green storage systems.

Constructed wetlands

Wetlands are marshy areas of shallow water partially or completely covered in aquatic vegetation, or "water-dominated areas with impeded drainage where soils are saturated with water and there is a characteristic fauna and flora"[42]. Other water bodies, such as vleis, water sponges, marshes, bogs, swamps, pans, river meadows, and riverine areas, are often called wetlands. Their ecological importance has been emphasised by the RAMSAR Convention in 1971, and many municipalities and industries are using artificial wetlands to treat wastewater.[43]

For the purposes of stormwater management, wetlands may be categorised into natural, modified natural, or constructed wetlands. The most common stormwater runoff pollutant treatment processes that occur in constructed wetlands are sedimentation, fine particle filtration, and biological nutrient and pathogen removal.

The effective functioning of a wetland is dependent on the presence of environmental conditions conducive to the required processes and the rate of hydraulic and nutrient loading. A major advantage is that wetlands are not dependent on external energy or chemical inputs and generally require little maintenance. Constructed or created wetlands simulate processes occurring in the natural wetland system. These may include:

- flood attenuation; and
- water quality improvement through the removal of substances such as suspended solids, nitrogen, trace metals, bacteria and sulphates.

In addition to their water purification functions, wetlands provide habitats and life-support systems for a wide range of flora and fauna, particularly birds, plants, reptiles and invertebrates. Wetlands can be aesthetically pleasing and offer an opportunity for recreation and education.

L.3.3.2 Elements of stormwater management systems

(i) Drainage of stormwater

Local topography and rainfall can lead to the formation of pans, dams and lakes, which form part of the conveyance route of stormwater until it finally infiltrates, evaporates, or reaches the sea. To protect the built environment, various man-made stormwater conveyance strategies and structures have been developed. Conventional drainage systems typically incorporate hard engineered structures such as pipes or culverts. The SuDS approach is to avoid hard structures where possible and provide for conveyance in swales or overland vegetation-lined drainage ways. The need to treat (alter and manage) the stormwater runoff of areas is primarily because of increased peak flows (normally due to development upstream), or to convey stormwater through and out of new developments. Erosion, flood, environment and health protection requirements should always be considered as part of conveyance. Design guidance for different drainage elements (infrastructure that conveys stormwater) is provided in Section L.4.2.2.

Channels

The main purpose of channels is to convey flows up to a certain RI within their cross-section. Channels should be designed to be 'fail-safe' so that the water level rises gradually if their design discharge is exceeded. Channels should also be designed to meet safety, maintenance and aesthetic requirements. Decisions about channel design should involve considering the following: conduit route; slope; cross-section shape; lining material (if materials other than concrete are chosen, careful attention must be given to durability and structural stability); flow regime (subcritical or supercritical flow conditions – the latter should be avoided wherever possible).

Land use, as well as environmental, economic and topographic considerations govern the route of a channel. The best channel route should follow the existing natural drainage lines. The slope of a channel tends to be the same as the natural ground slope; however, it could be made steeper (straightening of a winding natural channel), or flatter (incorporating drop structures or an aqueduct).

The selection of the channel cross-section and lining is governed by the site conditions, as well as by the character of the subgrade. For example, if space is limited and the subgrade is highly erodible, a concrete-lined channel with a rectangular or trapezoidal cross-section should be considered.

Photo credit: Wikimedia Commons - Nick D (L)[44], Nankai (R)[45]

Figure L.8: Examples of a stormwater channel (L) and a grass-lined swale (R)

- **Grass-lined channels (swales):** Often referred to as 'swales', grass-lined channels may have advantages over hard-lined channels in terms of aesthetic and recreational planning concerns, although they normally require higher maintenance. The presence of vegetative cover protects the soil from the erosive power of wind and water, reduces the runoff volume through infiltration, decreases flow velocities through retardation, improves water quality through filtration and various other biological processes, and can be aesthetically more pleasing if properly maintained.

- **Conduits:** The main purpose of conduits is to convey flows of a certain RI within its cross-section where an open channel is not suitable or desirable. Conduits should be able to convey flows greater than the design flood in a controlled manner and meet safety requirements and needs for maintenance. Decisions about conduit design involve a selection of the following: conduit route; slope; cross-section shape; material lining; and flow regime (subcritical or supercritical flow conditions).

  Land use, as well as environmental, economic and topographic considerations govern the route of a conduit. The best conduit route should generally follow the existing natural drainage lines. The slope of a conduit tends to be the same as the natural ground slope; however, it could be made steeper (straightening of a winding natural channel) or flatter (by decreasing the cover or using drop structures).

  The selection of the conduit cross-section, material type and joint type is governed by site-specific conditions and by overall planning concerns. For example, if the area is underlain with dolomite, a sealed joint should be considered.

- Transitions

  - **Kerb inlet transitions:** Kerb inlets (lateral stormwater inlets) are widely used with kerbs and surfaced roads. On moderate to steep road gradients, the capacity of kerb inlet transitions could be substantially improved by incorporating an extended length of depressed gutter upstream of the inlet. The effect of clogging should be minimised. More information is available in international literature.[46]

- **Kerb inlets:** The purpose of kerb inlets is to guide surface flow, e.g. from roads or parking areas, into the underground drainage system. The standards used by municipalities vary considerably. Generally, cognisance should be taken of the following: hydraulic performance; accessibility for cleaning purposes; ability of the top section of the culvert to bear heavy traffic; safety for all road users; and cost. Additional kerb inlet capacity of about 20% should be allowed to prevent blockages. More information is available from SAICE[47].

- **Culvert transitions:** Culvert transitions are structures that attempt to converge wide, shallow flow to pass through a narrow throat.

• **Road drainage:** The main function of urban roads is the carrying of vehicular, cycle, and pedestrian traffic. But they also have a stormwater management function. During minor storm events, these two functions should not be in conflict. During major storm events, however, the flood control function becomes more important as the roads 'double up' as channels and the traffic function is at least partially interrupted. It is thus essential that the road design and the stormwater design be done simultaneously. Coordinated planning between the road and drainage engineers is crucial at the pre-feasibility stage to ensure that the objectives of each service are met as comprehensively as possible.

It may be possible to design an integrated road and stormwater system that obviates the need for underground stormwater conduits altogether. This could for example be done by lowering the median between dual carriageways and draining the road pavements into them, instead of raising the medians as a physical barrier between the carriageways. This approach can lead to considerable savings and it allows the median to be designed as a swale with the attendant advantages of retention and water quality improvement. The pipes draining a median swale can often be considerably smaller than those required for draining the roads along the outside road shoulders. There may be a consequent space saving along the shoulders. Vegetated medians may not require irrigation as this will occur automatically through the drainage of the carriageways. Roundabouts at road intersections often provide an opportunity for the inclusion of bioretention areas with similar benefits to median swales. Road drainage issues related to unsurfaced roads; open channels; and the traffic-carrying capacity of roads are discussed below.

- **Unsurfaced roads:** The integration between the road and the stormwater drainage system becomes even more critical with unsurfaced roads. The drainage function of unsurfaced roads is dependent – and has a significant impact – on the planning of the road and access layout. If the roadway is to be used to channel and drain stormwater runoff, the velocity of this runoff should be such that minimal erosion potential exists (which implies flat longitudinal gradients). Roads with steep gradients should, as far as possible, not be used as drainage ways, nor should any adjacent side drains be used without proper protection against erosion. This protection can include drop structures, lined channels at critical sections, or regular drainage from the roadway into intersecting roads or drainage ways.

  Runoff from earth or gravel roads will contain grit and its conveyance in pipes can eventually block or damage the pipe network. Such blockages are difficult to clear. If maintenance is not done regularly, it will render the network ineffective. Use of pipelines in environments of high erosion potential is not recommended because of the high expense of maintenance and the high risk of failure or non-performance. Suitable protection against erosion of the canal invert, including drop structures and silt traps, is also important.

Photo credit: Wikimedia Commons - SuSanA Secretariat (R)[48]

Figure L.9: An example of erosion on an unsurfaced road (L) and lack of maintenance of an open channel (R)

- **Open channels:** Open channels – including swales (grassed open channels) – are an alternative to a network of pipes on the roadsides for conveying minor storm runoff. These may also convey dry weather flow in areas where the water tables are high or perched, and where the potential greywater/sullage from low-income households or from communal (shared) water points exist. The positioning of communal water points should be carefully considered and the appropriate drainage from these points should be included in their design.

  The use of open roadside channels may necessitate wider road reserves than those required to accommodate subsurface drains. This is particularly pertinent where open channels intersect with roadways or property access ways. The width of an open channel may increase progressively as the drain accepts more runoff. The road reserve may have to be widened or the channel deepened. Open drains, like all systems, will require maintenance; however, one advantage of an open channel system is that problems are not 'out of sight, out of mind'. Siltation and other problems will immediately become apparent.

  The crossfall of the road should generally be against the natural ground slope so that the whole road width can act as a drainage way in the major system. Protection against erosion on the downstream road edge may be required. Ideally, township layouts should be planned in such a way that the greatest length of road closely follows the ground contour (see Section F.4.3). Roadside channels are accessible, therefore safety considerations, especially relating to flow velocity or specific energy, are important.

- **Traffic-carrying capacity:** Stormwater runoff may affect the road's traffic-carrying capacity in the following manner:
  Sheet flow across the road surface – Sheet flow generated on a road surface is usually the least at the road crown, and increases towards the road edge. This can lead to hydroplaning, in other words when a vehicle travelling at speed has its tyres separated from the road surface by a thin film of water. Sheet flow can also interfere with traffic when splashing impairs the vision of drivers. Roads must be designed to avoid sheet flow crossing the traffic lanes, and attention must be paid to transition geometry.

Photo credit: Alexandra Renewal Project

Figure L.10: Examples of a river that has been restored

Channel flow along the road – Channel flow is generated from sheet flow and from overland flow from adjacent areas. As the flow proceeds, it increases in volume, encroaching on the road surface until it reaches a kerb inlet or drain inlet. The result is reduced effective road width. Splashing produced by car tyres can lead to dangerous driving conditions. It is important that emergency vehicles should still be able to use the road during major storms.

Ponding of runoff on road surfaces – Ponding on roads may occur at low points, at changes in gradient, at sump inlets, and at road intersections. This can have a serious effect on traffic flow, particularly as it may reach depths greater than the kerb height or remain on the roadway for long periods. A hazard of ponding is that it is localised; traffic may enter a pond at high speed, resulting in accidents.

Flow across traffic lanes – Flow across traffic lanes may occur at intersections when the capacity of the minor system is exceeded. As with ponding, localised cross-flows can create traffic hazards. Care should be taken to mitigate dangerous situations.

- **River restoration or renaturalisation:** Rivers and natural channels should ideally not be disturbed by construction activities. Should this be unavoidable, they should, under the guidance of appropriately qualified experts, be restored to such an extent that the channel would continue to behave in a hydraulic and ecological manner similar to that of the undisturbed natural stream. Failure to meet this requirement may lead to ecological collapse, erosion, and possible failure of drainage infrastructures. Newly constructed open channels must be properly integrated into the surrounding ecological, physical, visual, and social environments.

The morphology of urban streams is driven largely by hydrological changes in the catchment. Increased volumes of runoff and increased peak discharges will cause the stream to widen and deepen its channel. Along with increased frequency of runoff, these may destabilise the riparian vegetation that creates habitat diversity and helps protect the channel bed and banks against erosion. A stream rehabilitation plan should address the following:

- Returning the stream to a functional ecological condition, including establishment of habitat diversity
- Returning the stream to a functional morphological condition with a mix of features, such as meanders, pools, riffles, rapids, falls, bars, and bed and bank materials appropriate to the topography

- Re-establishing a flood regime of low flows, bank full flow, and overbank flow
- Restoring the riparian corridor, including replacement of alien invasive vegetation with suitable locally indigenous species to provide cover, resting, feeding, and breeding opportunities for animals and birds using the corridor
- Creating a socially and aesthetically attractive environment
- Ensuring sustainability of the recreated environment

The construction of rectangular channels with near vertical or stepped sides and level beds, using gabions or similar systems may be necessary under certain circumstances, but this cannot be defined as restoration or rehabilitation. Several publications give comprehensive guidance in the process of restoring urban streams.[49]

Relevant authorities should be consulted in the rehabilitation process as they may have special requirements for existing channels relating to riparian improvement programmes; soil conservation programmes; stream rehabilitation plans; natural channel design programmes; and ecological sustainability programmes.

(ii) Control structures

Weirs and orifices are structures widely used in hydraulic engineering to control or measure flow. Many of these structures are complex to analyse and difficult to build. Complex structures should only be considered in exceptional circumstances or where they are to be incorporated into the aesthetics of the structure as objects of urban sculpture. Design guidance is provided in **Section L.4.2.3**.

(iii) Detaining and retaining stormwater

Runoff can be stored in constructed basins. Such basins usually require large areas to be effective. Successful detention/retention of runoff may have to rely on several technologies, including detention ponds (detention facilities); rooftop detention; retention ponds; and/or wetlands. More information on SuDS regional controls to detain and retain stormwater is provided in **Section L.3.3.1 (iv)**. The feasibility should be investigated of harvesting rainwater either directly from roofs and impervious surfaces (as rainwater harvesting), or from the stormwater drainage system (as stormwater harvesting).

(iv) Stormwater outfall

The discharge from a proposed development, including the provision for the potential flow from the outside drainage area, should be either into a natural watercourse, or to a point of acceptance agreed upon by the landowner downstream and approved by the authority concerned. Stormwater system outlets should discharge stormwater of roughly equal quantity and quality than those of the pre-development conditions into receiving drainage ways at points that are least likely to erode. Discharge of stormwater should occur in a way similar to water that naturally entered the receiving system, for example if a wetland naturally received distributed surface and subsurface inflow, the stormwater outlet should mimic this regime. Design guidance for outfall management is provided in **Section L.4.2.4**.

The discharge of stormwater from a planned development should not be concentrated on a downstream property where it was not concentrated before, unless a servitude for conveyance of the stormwater is acquired to cross that property and any other low-lying properties until it reaches a specific point of discharge. The post-development peak flow rate may not exceed that of the pre-development peak rate of flow (see **Section L.4.1.1** for guidance on the modelling of peak flow rates). If the rate of runoff is increased, or may aggravate an existing problem post-development, stormwater management satisfactory to the controlling authority system should be provided to preclude any adverse impacts related to the higher or concentrated flow rate. Every outfall structure is a potential source of water that could, through innovative planning, be used as a valuable resource.

L.3.3.3 The dual drainage system

The dual system incorporates a 'minor system' for the frequent storm events and a 'major system' for the less frequent but severe storm events (see **Section L.2.3.5**). The main functions of minor systems are to ensure convenience to the public and compliance with regulatory targets, while the major system operates during overflow from or failure of the minor system, generally during major or infrequent storm events. It includes natural watercourses, large conduits, roads, stormwater attenuation facilities (ponds), drainage servitudes, wetlands and flood plains. Public open spaces, sports fields and parking areas can also be utilised to form part of the major system.

(i) Minor systems

Minor systems are usually managed by setting targets to best control the following measurable parameters of stormwater runoff: peak discharge rate; total volume of runoff; frequency of surface runoff; and water quality. The minor system supports the major system by mitigating the risks that might result from more frequent storms. The main functions of minor systems are to ensure convenience to the public and compliance with regulatory targets.

The minor stormwater system minimises the nuisance value of storms with relatively frequent recurrence intervals (typically from 2 to 10 years, depending on the development). Ideally, at least the first 25-30 mm of rainfall (typically 1:3 months to 1:6 months RI) – which is the most polluted – is managed via SuDS source controls (green roofs, rain harvesting, permeable pavements, etc.) or SuDS local controls (infiltration trenches, bio-retention areas, etc.). Surplus water may be conveyed via swales, catchpits, road-edge channels, pipes, etc. to SuDS regional controls (ponds, wetlands, etc.). There it is temporarily stored and treated (sometimes harvested) before being released into the natural drainage system in a controlled manner that emulates the natural runoff process. Direct conveyance of stormwater from source to receiving water from an urban area without some form of treatment is strongly discouraged, as it frequently results in heavy downstream environmental costs. Table L.4 shows the minimum flood frequencies to be used for initial planning of minor systems per land use type.

Table L.4: Flood frequencies for minor system planning

Land use	Design flood recurrence interval
Residential	1 - 5 years or more in informal areas to ensure sufficient space to convey runoff
Institutional (e.g. schools)	2 - 5 years
General commercial and industrial	5 years
High-value central business district	5 - 10 years

The indications in Table L.4 and Table L.5 are guidelines, and the onus is on the drainage engineer to determine the risk associated with a certain recurrence interval. For areas where the risk to life, or the risk of monetary loss, loss of revenue, or loss of utilities is unacceptably high, a more stringent (or higher) recurrence interval and a higher level of service may need to be considered. For large structures such as bridges and major culverts, consult the Department of Transport's *Guidelines for the hydraulic design and maintenance of river crossings*[50].

(ii) Major systems

Major systems usually comprise roads, public open space and servitudes that will generally be free of major obstacles to overland flow. Although it is common for designers to assume that the minor system (see previous section) is available to assist with major floods, this is often not the case, as inlets and channels are easily blocked by debris. It is safer to assume no assistance from the minor system.

Natural streams, even where highly affected and degraded, form part of the major system and should receive special attention to ensure minimal damage in the event of a major flood. During a major flood, temporary disruption of many normal activities within the catchment will occur; the loss of convenience is tolerable if no inundation of private property occurs up to the design recurrence interval and the disruption is restricted to residential and lower-order roads, recreational areas and public open space, and parking areas.

The major system can be supported by the minor system, and can accommodate the unusually high runoff from infrequent hydrologic events. Its main function is to ensure public safety and protection of the built and natural environment during such events. A 100-year RI flood line is required on residential development plans in terms of the National Water Act. The minimum flood frequency to be used for initial planning of major systems, irrespective of land use, is an RI of 100 years. A more conservative approach (up to PMF/RMF) should be considered for vulnerable communities or where high hazard activities (sanitary land fill, cemeteries, fuel storage, etc.) are envisaged. Essential community facilities, especially those that are likely to play an important role in the event of significant flooding, also require a more conservative approach. The likely impact of climate change should be considered. Minimum design RIs applied in Australia are given in Table L.5 and could be used for South African situations.

Table L.5: Design Recurrence Intervals of essential community infrastructure

Type of essential community infrastructure	Design Flood Recurrence Interval
Emergency services (fire station)	500 years
Emergency services (emergency shelter)	200 years
Emergency services (police station)	200 years
Hospital and health care services	500 years
Community facility (storage of valuable records or items of historic or cultural significance, e.g. galleries and libraries)	200 years
Power station or renewable energy facility	500 years
Major electricity infrastructure (major switch yard)	500 years
Substations	200 years
Utility installation (water treatment plant)	200 years

It is important to note that the lifetime risk is much greater than the annual risk. The default value may therefore not be appropriate and planning should be considered for a much longer recurrence interval, the RMF or PMF. The concepts of best management practices (BMPs)[51], good practice, or best available technology not entailing excessive cost (BATNEEC) may require that more stringent recurrence intervals be considered. Municipalities may also stipulate more stringent flood lines, depending on the development type and location.

L.4 Design considerations

Once the elements of an appropriate stormwater management system have been identified, the infrastructure can be designed. This section first provides guidance on the modelling criteria for the design of stormwater systems and then guidance on the various elements of minor and major systems. The section concludes with highlighting important operation and maintenance considerations.

L.4.1 Modelling criteria for the design of stormwater systems

The runoff rates and volumes of storm events, determined by hydrological simulation, define the required capacity of the interventions and conveyance options for the specified design event. The facility dimensions necessary to achieve the required capacity are determined by hydraulic calculation.

L.4.1.1 Design peak flow rate

The design peak flow rate should ideally be determined by computer modelling by using one of the many commercially available software packages. A combination of other statistical methods (based on measured runoff data), empirical relationships, or deterministic methods (Rational, Unit Hydrograph, Standard Design Flood (SDF) and Soil Conservation Services (SCS-SA)) may also be used – either alone or in conjunction with computer modelling.

(i) Statistical methods

Statistical methods involve the use of historical data to determine the design flood for a given period. The use is limited to catchments with suitable long flow records. Statistical methods are recommended when suitable data is available. Any extrapolation of such data records should be handled with caution, as statistical methods assume a stationary data set – trends that are due to climate change or changing land use in the catchment are not reflected.

(ii) Empirical methods

Empirical methods, for example the Regional Maximum Flood (RMF)[52] and the Probable Maximum Flood (PMF)[53,54] are important tools for determining the peak discharges of rare flood events for risk analysis. Refer to the *SANRAL Drainage Manual*[55] for guidelines on these methods.

(iii) Deterministic methods

The Rational Method

The Rational Method – the conservation of mass adjusted by the runoff factor – is recommended for small catchments (15 km^2 maximum) only. Uniform temporal and spatial distributions of rainfall and a constant runoff factor are assumed, but these are only accurate for small impervious catchments. A first estimate of the peak flow in a drainage system can be obtained by using the Rational Method.

$$Q = C \times i \times \frac{A}{3.6}$$

Where:
Q = design peak runoff rate (m^3/s)
C = runoff coefficient (0 – 1 where 0 indicates no runoff and 1 indicates complete runoff)
i = rainfall intensity (mm/hr)
A = catchment area (km^2)

A first estimate of the runoff volume may be determined as follows:

$$RV = C \times A \times d$$

Where:
RV = runoff volume (m^3)
C = runoff coefficient
A = catchment area (km^2)
d = rainfall depth from the Rational Method Depth Duration Frequency (DDF) curve (mm)

The Unit Hydrograph Method

The Unit Hydrograph Method is based mainly on the regional analyses of historical data and is independent of personal judgement. The results are reasonably reliable for medium-sized rural catchments (15 to 5 000 km^2). The typical minimum time step in the S-curve method of hydrograph derivation is one hour, which is regarded as too long for most stormwater management calculations.

The Standard Design Flood method

The Standard Design Flood (SDF) method[56] provides a uniform approach to flood calculations. The SDF method is based on calibrated discharge coefficients for recurrence periods of 2 and 100 years. These calibrated discharge parameters are based on historical data for 29 homogeneous basins in South Africa. The method is applicable to catchments between 10 km^2 and 40 000 km^2 in area. It should be used with caution because of its assumption that the local catchment conditions are the same as the regional basin characteristics that were used to derive the parameters, which are unlikely in the case of an urban catchment.

The Soil Conservation Services method

The Soil Conservation Services (SCS-SA) method[57] is suitable for calculating catchment runoff volumes for catchments smaller than 30 km^2. The method considers factors that affect runoff such as soil moisture, soil type and rainfall.

(iv) Computer models

Computer models are models where the catchment is represented by smaller sub-catchments of consistent characteristics (topographical slope, imperviousness ratio, soil characteristics, etc.) and the drainage system by a linked network of conduits representing the drainage pattern of the catchment. Runoff from sub-catchments is computed as a function of rainfall that may be a measured continuous time series, or a design storm derived from the local Intensity Duration Frequency (IDF) curves.

Flow in the conduits is computed by aggregating the runoff hydrographs from the sub-catchments and routing resulting hydrographs down the drainage network. Computer models can be extended to include groundwater and water quality parameters.

L.4.1.2 Storage capacity

In the initial stages of the design of storage ponds, it should always be considered what the consequences would be when the design storm is exceeded and whether an emergency overflow has been provided for to ensure the pond is not breached in an uncontrolled manner.

The storage capacity of a basin is determined as follows:

$$V = \sum_{i=0}^{n} \frac{A(i) + A(i+1)}{2} \times di$$

Where:
V = storage volume (m^3)
$A(i)$ = surface area at elevation i (m^2)
$A(i+1)$ = surface area at elevation $i+1$ (m^2)
di = vertical height difference (m)
n = number of horizontal sections
i = integer variable

The required storage for Water Quality Volume (WQV) can be computed as follows:

$$WQV = P \times C \times A \times 10$$

Where:
WQV = Water Quality Volume (m^3)
P = total rainfall depth to be included (mm) (typically 25 mm or use the Rational Method depth for specific RI)
C = runoff coefficient (0.05 – 0.95)[58]
A = total drainage area (ha)

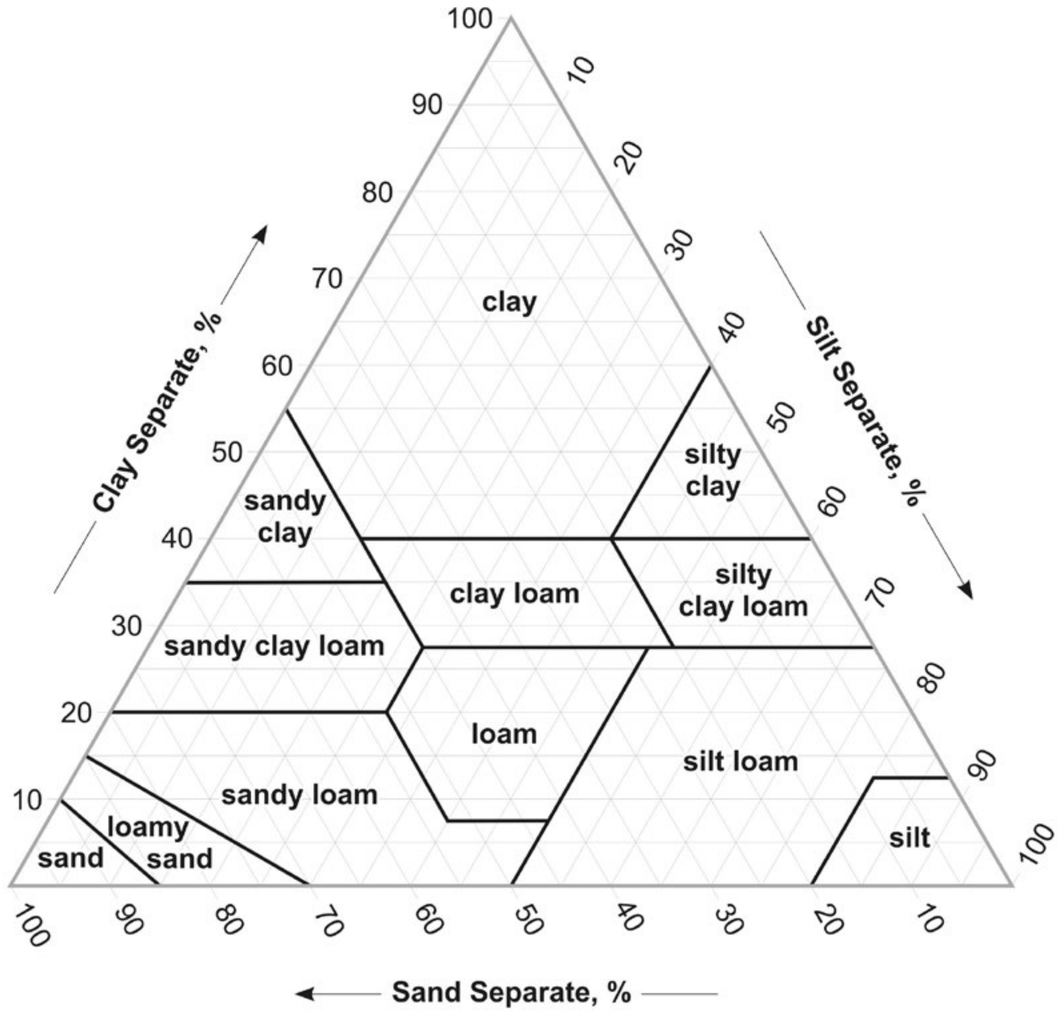
L.4.1.3 Infiltration

A geotechnical investigation should be performed prior to the design to ensure that infiltration-type SuDS can perform effectively. It is important to check the structural stability of adjoining soils, structures and services as well as the presence of groundwater pollution before designing infiltration systems. In the case of groundwater pollution, pre-treatment may be necessary.

The coefficient of permeability depends on many factors and is likely to change over time, but Table L.6 and Figure L.11 can be used as a first estimate, based on the grading analysis of the soil. A notable exception is the Halfway House Granites where there is little downward flow. Most transverse flows occur in well-defined strata within the soil column.

More information and guidance on the calculation of the hydraulic characteristics of soils can be found in Saxton *et al*[59].

Table L.6: Typical Soil Texture Permeability Coefficients[60]		
Soil texture	**Permeability coefficients (mm/h)**	**Adequacy**
Gravel	10 000 - 1 000 000	Generally inadequate treatment
Sand	100 - 100 000	
Loamy sand	10 - 1 000	Yes
Sandy loam	50 - 500	
Loam	1 - 100	
Silt loam	0.5 - 50	
Sandy clay loam	1 - 100	
Silty clay loam	0.05 - 5	No
Clay	<0.1	
Unstratified soil	0.01 - 10	
Rock	0.01 - 100	



Acknowledgement: United States Department of Agriculture[61]

Figure L.11: Soil texture triangle

L.4.1.4 Water quality

Runoff from urban environments can be highly polluted. Efforts to reduce this pollution should be coordinated between those responsible for refuse removal, sanitation, and industrial effluent.

There is no single treatment process for treating stormwater economically for all pollutants. A combination of treatment processes could be used to improve the water quality and/or reduce erosion. The actual combination and treatment processes that are selected depend on the nature of the pollutant load and the desired water quality standard.

Three common constituents are normally tested for: E.coli, blue green algae, and algal pigments. To adequately cover the site-specific needs of the project, testing should not be limited to these three constituents, but should be informed by the site-specific conditions and guided by the water quality standards set by the DWS. Pollution abatement measures in applying SuDS are presented in Table L.7.

Table L.7: SuDS Water Quality[62]				
SuDS <u>OBJECTIVES</u>	Greenfield developments <u>and</u> Brownfield and existing development sites located in catchments of sensitive receiving water systems	Brownfield and existing development sites >50 000 m^2	Brownfield and existing development sites 4 000 m^2 – 50 000 m^2 <u>and</u> Total impervious area (existing and new) >15% of site	Brownfield and existing development sites <4 000 m^2 <u>and</u> Total impervious area (existing and new) > 600m^2
	Design storm event for water quality treatment: ½-year RI, 24 h storm			
<u>IMPROVE QUALITY OF RUNOFF</u> Remove pollutants through combination of reducing and/or disconnecting impervious areas and the use of best management practices to infiltrate or capture and treat stormwater runoff	Pollutant removal target: Reduction of post-development annual stormwater pollutant load discharged from development site: SS and TP – reduce to undeveloped catchment levels <u>or</u> SS – 80% reduction TP – 45 % reduction *Whichever requires higher level of treatment*	Pollutant removal target: On-site reduction of post-development annual stormwater pollutant load discharged from development site: SS – 80% reduction TP – 45 % reduction	Pollutant removal target: Combination of on-site and regional off-site measures to achieve target reductions: SS – 80% reduction TP – 45 % reduction	On-site stormwater treatment not required but encouraged where practicable. Regional off-site treatment measures to achieve target reductions: SS – 80% reduction TP – 45 % reduction
	All development are required to trap litter, oil, grease at source			

Note: SS = Suspended Solids; TP = Total Phosphorus

L.4.2 The design of a minor system

L.4.2.1 SuDS interventions

This section provides design guidance on SuDS source controls, local controls and regional controls (see Section L.3.3.1).

The conceptual design process to assist in both the development process and the conceptual design of a minor system includes the following:[63]

- **Project summary**
  - Site investigation
  - Formulate criteria (quantity; quality; amenity; biodiversity)
- **Hydraulic assessment**
  - Flood risk assessment
  - Greenfield runoff rates and volume assessment
  - Development runoff rates and volume
  - Interception storage
  - Water Quality Volume (WQV)
  - Infiltration assessment
- **Preliminary design**
  - Treatment train conceptualisation and assessment
  - Conveyance system layout
- **Modelling**
  - Treatment train modelling
  - Water balance calculation
- **Final concept**
  - SuDS design refinement by varying storage volumes; treatment train design; conveyance design
- **Implementation**

(i) SuDS source controls

SuDS source controls (introduced in Section L.3.3.1) that can be used as part of minor stormwater systems include green roofs, stormwater harvesting, soakaways and permeable pavements.

Green roofs

Flat or gently sloping roofs (0 to 20 degrees) can be vegetated according to the typical cross-section showed in Figure L.12, on condition that the structural capacity is adequate, water proofing is done well, and suitable indigenous vegetation is used (to be specified by a landscape architect). The section applies only to extensive (shallow) green roofs. Other options, such as intensive green roofs, blue roofs, green walls, etc., require specialist input.

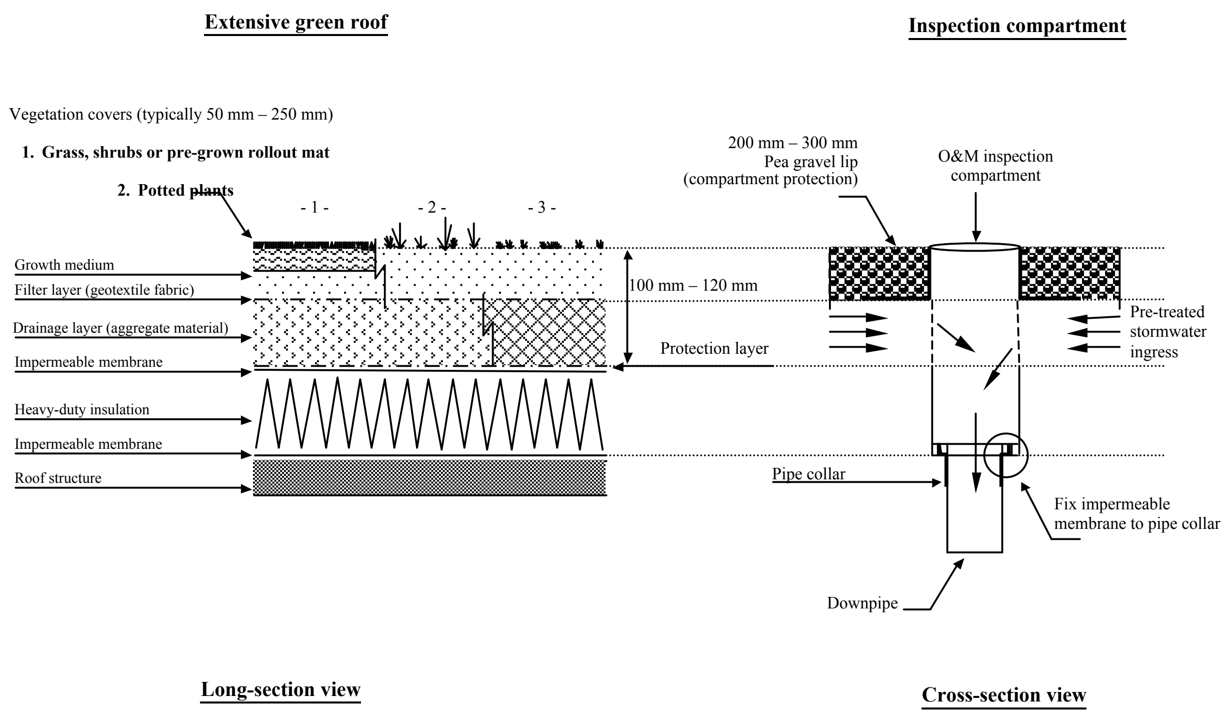


Figure L.12: General design for green roofs and adjoining inspection compartment

Stormwater harvesting

The quality of harvested stormwater 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.[65,66] Careful choice of fabrication materials is important to avoid dezincification of brass, or rapid corrosion of galvanised sheeting. The following should be considered when designing a stormwater harvesting facility:

- The strategic placement of catchment structures
- A first-flush trap and/or filter sock to catch leaves and other debris
- A water storage facility (tank, barrel or sump)
- Leaf and organic debris diverters
- A means of getting the water to its point of use, preferably by gravity
- An in-line filter and/or UV disinfection device if there is any risk of human contact
- An overflow system – preferably linked to an option in a SuDS treatment train

The volume of usable rainfall can be estimated as follows (see **Section J.4.2.3** for design guidance on rainwater harvesting from roofs):

$$V = R \times A \times C \times FE$$

Where:

V = Volume of usable rainwater (L)
R = Average rainfall over period – usually monthly (mm)
A = Area contributing to runoff (m^2)
C = Runoff coefficient (0-1)
FE = Filter Efficiency (0-1) – if applicable – usually 0.9

Runoff coefficients are variable and dependent on the antecedent moisture conditions and the depth of rainfall. The coefficient for a particular storm rainfall depth can be estimated as follows:

$$C = (1 - \frac{Ia}{\mathrm{p}})$$

Where:

Ia = Initial abstraction (mm)
P = Precipitation depth of event (mm)

Typical runoff coefficients for different surfaces are presented in Table L.8.

Table L.8: Runoff coefficient for different surfaces[67]

Surface of catchment	Coefficient
Tiles	0.8 – 0.9
Concrete and asphalt	0.9
Metal (corrugated iron, flat iron sheet, IBR profile)	0.95
Tar and gravel	0.8 – 0.85
Thatch	Not suitable for rainwater harvesting

The actual yield of a stormwater harvesting system is a function of the variability of the rainfall, the runoff efficiency of the catchment, the volume of storage provided, and the rate of abstraction. A properly designed system will balance the components to optimise yield and cost. Storage requirements can be estimated using a Rippl diagram[68] or by modelling based on daily rainfall and expected demands. Harvested rainwater can be used directly for site irrigation or non-potable domestic purposes or, with suitable treatment, as potable water.

Soakaways

The following should be considered when designing a soakaway:

- The permeability of the soil at different depths should be determined (digging a deep soakaway pit when the bulk of the outflow is horizontal or downslope via the leached upper horizons of the soil profile will be pointless). These values can be measured by specialist hydro-pedological testing or measured by conducting infiltration tests at different depths in the soil.
- Fine-grained material should be prevented from washing into the soakaway (either allow the influent water to flow over a grassed verge or provide a sediment trap). Consider a geotextile for fine-grained material, but be careful of the chemistry of some groundwater that may precipitate insoluble salts, which will rapidly block the pores of the geofabric.

- The soakaway should be able to drain 50% of design storm in 24 hours.
- Soakaways should mostly be used for areas smaller than 1 000 m^2.
- To prevent groundwater contamination, soakaways should be constructed at least 1.5 m above the groundwater table to allow for additional filtration[69].

The effective storage volume of a stone fill soakaway is calculated as follows:

$$V_{eff} = V_{tot} \times Porosity\ (n)$$

Where:
V_{tot} = total volume occupied by the stone fill

Note that porosity should not be confused with voids ratio:

Porosity: $n = \frac{V_v}{V_t}$

Voids ratio: $e = \frac{V_v}{V_s}$

Where:
V_v = Volume of voids containing either air or water
V_s = Volume of solids
V_t = Total volume

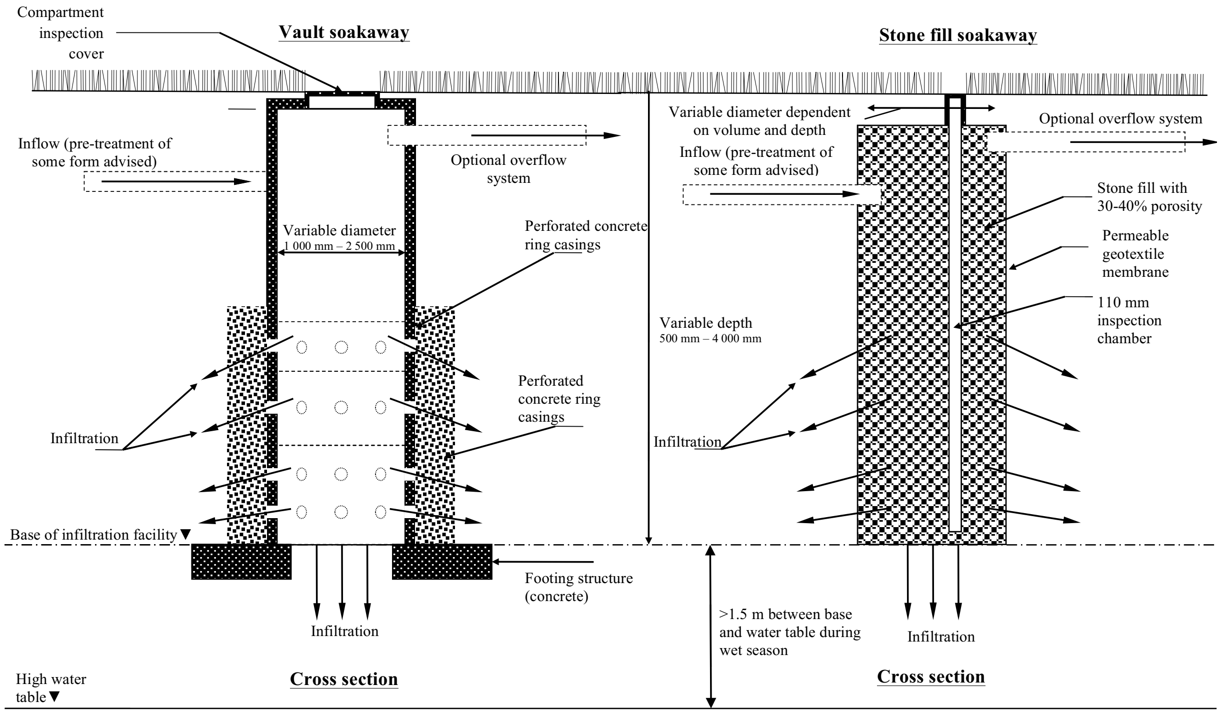
The values for n and e can be calculated from each other as:

$n = \frac{e}{(1 + e)}$ or $e = \frac{n}{(1 - n)}$

Estimating the infiltration rate

A method for estimating the infiltration rate involves the following: Dig a hole 1 m x 1 m to the desired depth and in the bottom of this, dig a smaller hole 0.3 m x 0.3 m x 0.3 m deep. Fill the smaller hole with water and record how long it takes for the water level to drop by an accurately measurable depth, refill the hole and again record the time it takes for the water level to drop a measured depth. Repeat this procedure 5 or 6 times at intervals until the rate of drop is approximately constant. For each refilling, calculate the rate of drop in mm/h. Then plot the rate of drop against the elapsed time. The resulting curve should show an infiltration rate that decays exponentially with time to some equilibrium value, which can be used to estimate the rate at which water will soak out of the soakaway.

A number of documents give guidelines for the design of soakaways[70,71,72]. Typical soakaway arrangements are shown in Figure L.13, but remember that the sides do not need to be vertical; it is easier and safer to dig a hole with sloping sides.



Acknowledgement: Armitage et al.[73]

Figure L.13: General designs for soakaways

Permeable pavements

Runoff rates and volumes should be modelled for the design of permeable pavements. Many commercial software packages are available, but a first estimate can be obtained by using the Rational Method discussed in Section L.4.1.1. Typical porosity of the reservoir medium is about 0.3, excluding run-on. The depth of the reservoir layer should be about three times the design rainfall depth. A reservoir layer 0.35 m thick would therefore store about the 20-year RI 1-day rainfall depth in Johannesburg. The following should be considered when designing permeable pavements:

- Meticulous attention should be paid to detail during design and construction, as permanently saturated pavement layers result in significantly reduced shear strength.
- Any materials used – particularly stone – should be properly cleaned prior to installation or they will introduce pollutants into the outflow. In the case of stone, this should be washed until there is no more visible sediment coming off the material. Beware of soil from tree-pits or surrounding embankments that could wash over the pavers rendering them impermeable.
- Permeable pavements should preferably be used in lightly trafficked applications such as residential driveways, parking areas, private roads, cycle pathways, walkways and terraces.
- The entire volume from the design storm over the paved area should be captured and the excess flows should be treated. Fine-grained material should be prevented from washing onto the surface of the paving.

- A suitable geotextile should be laid for fine-grained soils or in places where the flow between the permeable pavement and the underlying soil is of concern.
- Polymer-based geofabrics placed between the bedding layer and the reservoir layer can help trap and degrade hydrocarbons, but they can also lead to premature blocking. Therefore the outlet where the permeable pavement is constructed should be raised with an underdrain – creating a semi-permanent 'reservoir' in the base of the pavement layers.
- Since the transverse conductivity of the reservoir layer is high, the initial design should assume that the water surface in the reservoir layer is horizontal. Permeable pavements are only suitable for use on very flat slopes.
- Permeable pavements should be maintained by periodical cleaning using specially designed vacuum trucks equipped with rotating brooms, or by hand. It is usual to design the surface infiltration rates with a safety factor of 10, i.e. theoretically 90% of the surface can be blocked before remedial action is required – which could include reconstruction of the pavement. Keeping the local environment relatively clear of dust can significantly extend the time between maintenance activities.

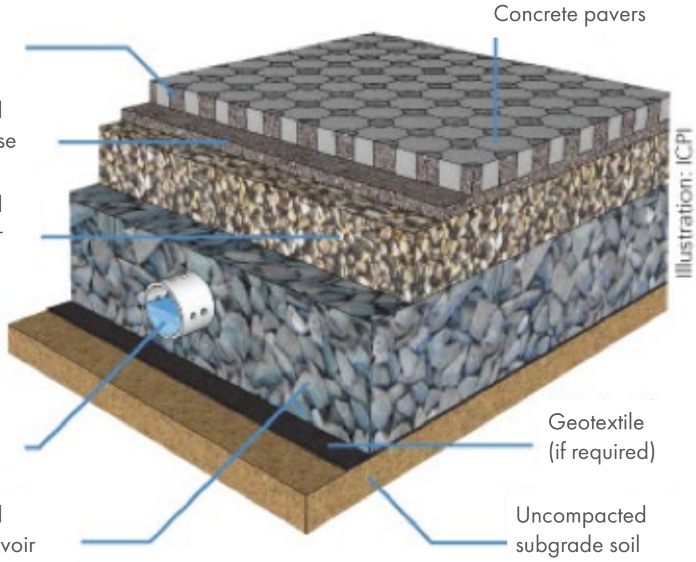


Figure L.14: Typical arrangement of a permeable pavement system

Acknowledgement: Interlocking Concrete Pavement Institute (ICPI)[74]

(ii) SuDS local controls

This section provides design guidance for SuDS local controls (introduced in **Section L.3.3.1**) that can be used as part of minor stormwater systems. These SuDS local controls include filter strips; swales; infiltration trenches; bioretention areas; rain gardens and bioretention cells; bioswales; and sand filters.

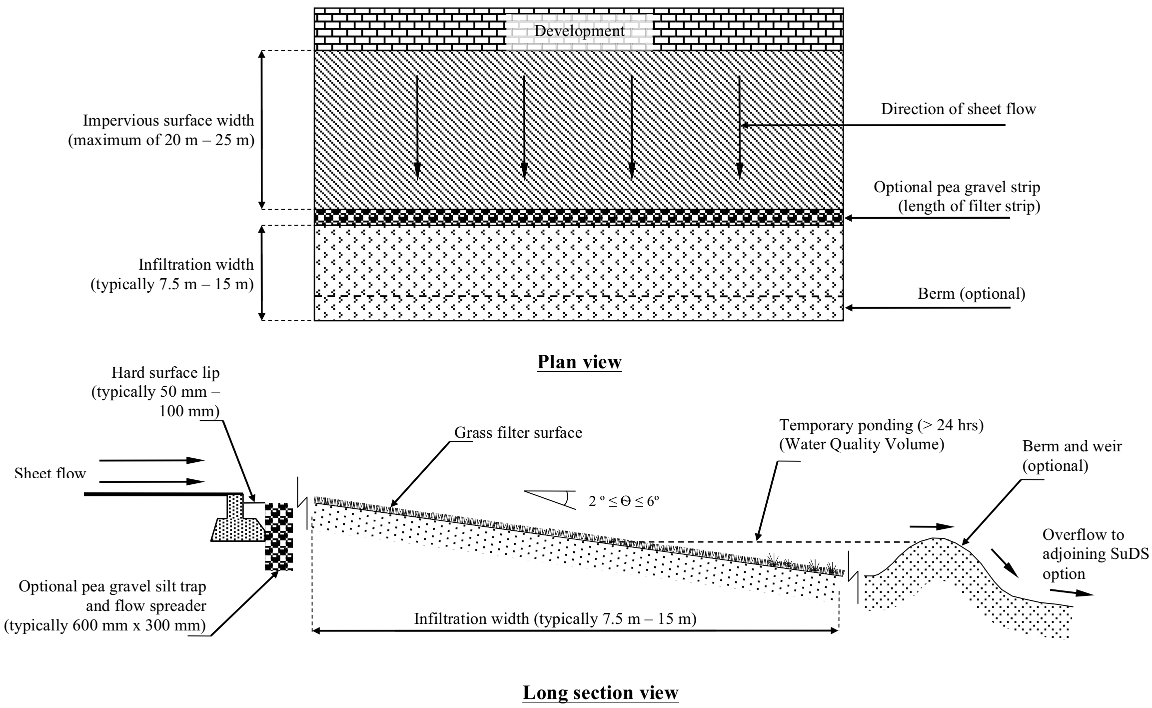
Filter strips

The following should be considered when designing filter strips:

- Filter strips rely on even distribution of flow, thus channelling or rilling must be avoided
- Filter strips are used to manage shallow overland stormwater from low-density developments

- Filter strips are commonly used along stream banks as vegetated buffer or to intercept sheet flow from large parking areas and arterial roadways
- A 24-hour rainfall of 0.5 year to 1 year recurrence interval should be designed for
- Filter strips are normally used to serve areas smaller than 20 000 m^2 with slopes between 2% and 6%
- Maximum flow velocity for filter strips is 0.3 m/s
- Consider clogging of subsurface material

Typical filter strip arrangements are shown in Figure L.15.



Acknowledgement: Armitage et al.[75]

Figure L.15: Design for filter strips and adjoining silt trap and berm

Swales

The following should be considered when designing swales:

- Shallow grass-lined channels with flat side slopes serve as alternative to kerbs and gutters for low-density residential developments
- Side slopes should be flatter than 1:3 V:H (18 degrees) for stability and maintenance
- Swales are often used with bioretention facilities in a treatment train
- Swales are suitable for road medians and verges, parking runoff areas, parks and recreation areas
- Design RI should be used for the minor system

- Site constraints should be taken into account when designing the design flows and resultant dimensions (usually parabolic or trapezoidal)
- Maximum permissible velocity depends on the characteristics of the subgrade soil and the type of grass and grass length
- Standing water should be prevented by ensuring a consistent gradient
- The likely treatment performance should be determined and plant species and planting density should be specified
- Design inflow should be optimised and verified with scour velocity and treatment performance checks
- Overflow areas should be sized
- A maintenance plan should be drafted

Typical swale arrangements are shown in Figure L.16.

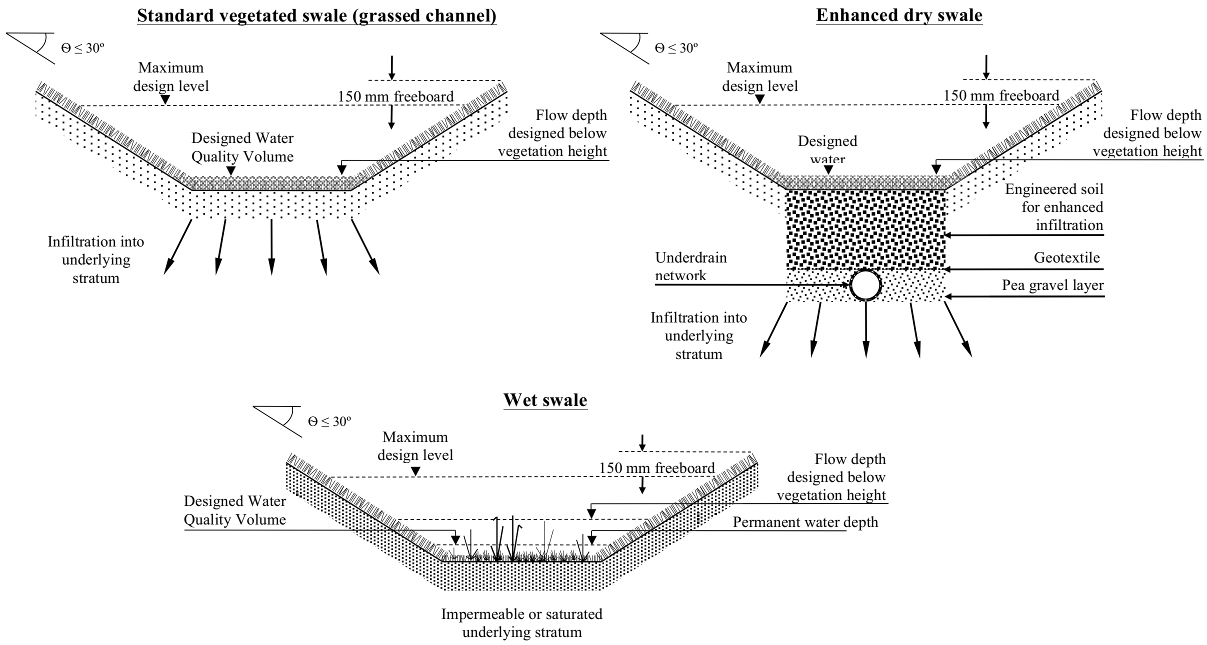


Figure L.16: Design for swales

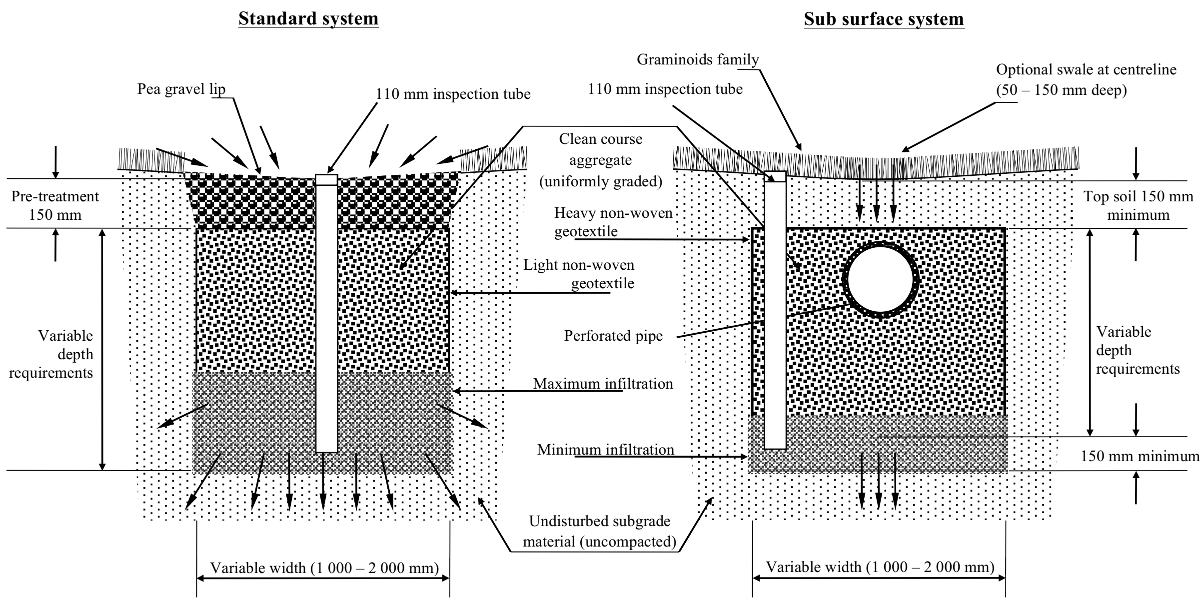
Acknowledgement: *Armitage et al.* [76]

Infiltration trenches

The following should be considered when designing infiltration trenches:

- The infiltration rates in the surrounding soil stratum
- The required stormwater treatment flow rates
- The type of porous media to be used for backfilling the trench
- The geology of the area (this will affect the potential flow path of the infiltrated water, e.g. the Halfway House Granites in Gauteng could result in saturation of downstream foundations where the bed rock is shallow)
- The clogging potential of the trench

Typical infiltration trench arrangements are shown in Figure L.17.

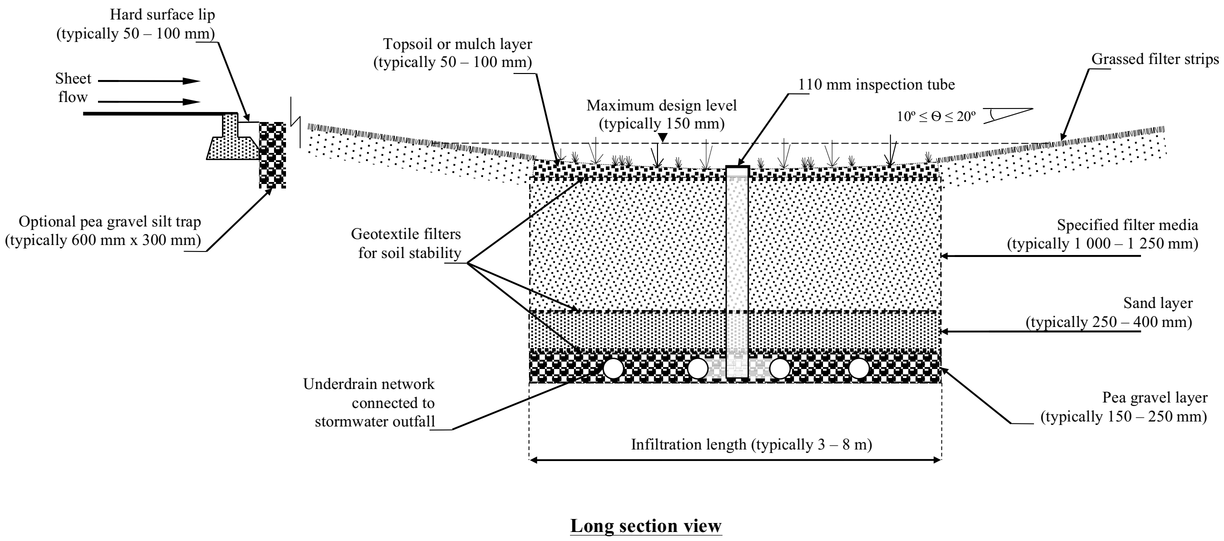


Acknowledgement: *Armitage et al.*[77]

Figure L.17: General design for dual infiltration trenches

Bioretention areas

Typical bioretention area arrangements are shown in Figure L.18.



Acknowledgement: Armitage et al.[78]

Figure L.18: Design for bioretention

Rain gardens and bioretention cells

A rain garden differs from a bioswale in that it has no linear drainage component, water is lost by spill, infiltration, and evapotranspiration. Water quality is improved by sediment trapping and by the biological and chemical processes that take place in the root zone. Runoff is reduced by infiltration and evapotranspiration, and it is attenuated by the storage in the surface pond and in the porous growing medium, as well as by the gravel drainage medium. Rain gardens and bioretention cells comprise some or all of the following (rain gardens are bioretention cells without the gravel storage medium):

- A surface open water pond that will usually be temporary
- A mulch layer at least 50 mm thick
- A growing medium that should be a special mix of reworked natural soils (this is likely to compact and lose permeability over time)
- A gravel storage medium
- The subgrade

It may be necessary to provide a separation layer between the gravel storage medium and the subgrade below and the growing medium above. Chemical precipitates or biological slime layers can rapidly block geofabrics, therefore the use of graded filter layers is preferred.

The planting medium in the rain garden should be sufficiently permeable to ensure infiltration of the surface water. Depending on the infiltration capacity of the subgrade, the water in the growing medium will gradually drain away until the field capacity of the soil is reached after two or three days, and continue to be lost by evapotranspiration until the wilting point is reached.

Water quality in biocells is improved by sediment trapping, by the biological and chemical processes that take place in the root zone, and by filtration as the water percolates through the growing medium. Organic contaminants, such as polycyclic aromatic hydrocarbons (PAHs), can be trapped in the soil and oxidise chemically or by biological action over time. Pathogens can be deprived of nutrients or predated by heterotrophic soil organisms. Nutrients are typically taken up by plant growth. Phosphorous is a persistent nutrient that will have to be removed by harvesting plant growth. Heavy metals can concentrate in the growing medium and gradually poison the soil.

The planting medium in the biocells should be sufficiently permeable to ensure infiltration of the surface water, but not so permeable that the water runs straight through. Water should be retained long enough for the bioremediation processes to be effective. The growing medium is underlain by a drainage medium similar to that of a golf course green. When there is no hydraulic gradient through the growing medium, the water is affected by capillary action because it cannot easily flow across the interface between the finer growing medium and the coarser drainage material. The water will gradually drain away until the capacity of the soil is reached after two or three days.

The planting medium should also have sufficient organic content for good plant growth and to help retain water. A typical mix would be 70% washed river sand, 20% topsoil from the site if it is not too clayey, and 10% sifted compost. At least 50 mm of mulch should be placed on the surface immediately after planting and replaced or topped up annually.

Plant selection can be difficult, especially in the case of no irrigation. In the dry season the temperatures are high enough for significant evaporation to take place (in Gauteng potential evaporation is about 120 mm/month even in July), and in the wet season there may be quite long periods between rainfall events. The wilting point of the soil can be reached quite often during either season. Conditions in the rain gardens may be quite extreme, from inundation to wilting point, several times per year.

Bioswales

A bioswale comprises some, or all, of the following:

- A surface flow channel with intermittent flow. Densely planted or covered with gravel or cobbles to prevent erosion. Side slopes flatter than 1:5 (V:H) and a longitudinal slope less than 1:200. Small steps may be required at intervals to reduce the slope.
- A mulch layer at least 50 mm thick if the channel is planted.
- A growing medium that may be a special mix, or simply reworked natural soil if it has suitable characteristics.
- A gravel storage and drainage medium.
- An agricultural drain embedded in the gravel drainage medium.
- The subgrade.

If the relative gradings of the subgrade and the component soils of the bioswales allow it, geofabrics should be avoided if the chemistry of the groundwater indicates that blockage by metal precipitates is possible.

Sand filters

Sand filters are generally used for impervious areas of less than 8 000 m^2. Sand filters can be difficult and costly to maintain, especially because the 'out-of-sight – out-of-mind' principle will often apply. Careful consideration should be given to the use of alternative interventions. Sand filters are most commonly used in areas of fine soils and relatively low associated infiltration rates; in arid regions with high evaporation rates where limited rainfall and high evaporation rates preclude the utilisation of retention ponds or wetlands for stormwater management; in areas where there is limited open ground and where sand filter systems can be implemented beneath impervious surfaces; and when there is a significant requirement to protect groundwater resources.

(iii) SuDS regional controls

This section provides design guidance for the SuDS regional controls (introduced in **Section L.3.3.1**) that can be used as part of minor stormwater systems. These SuDS regional controls include detention ponds; retention ponds; outlet structures; and constructed wetlands.

Detention ponds

The following should be considered when designing stormwater detention ponds:

- The local catchment hydraulics and hydrology (the sizing and positioning should form part of the master drainage plan)
- Guidelines for RI and total volume requirements
- The implementation of appropriate safety structures, including disease vector controls
- The prevention of dangerously steep ground slopes around the pond perimeter
- Safe and obvious escape routes
- Design outlets for people or animals to not be trapped by water pressure
- The prevention of erosion at the inlet
- Upstream treatment systems and outlet structures

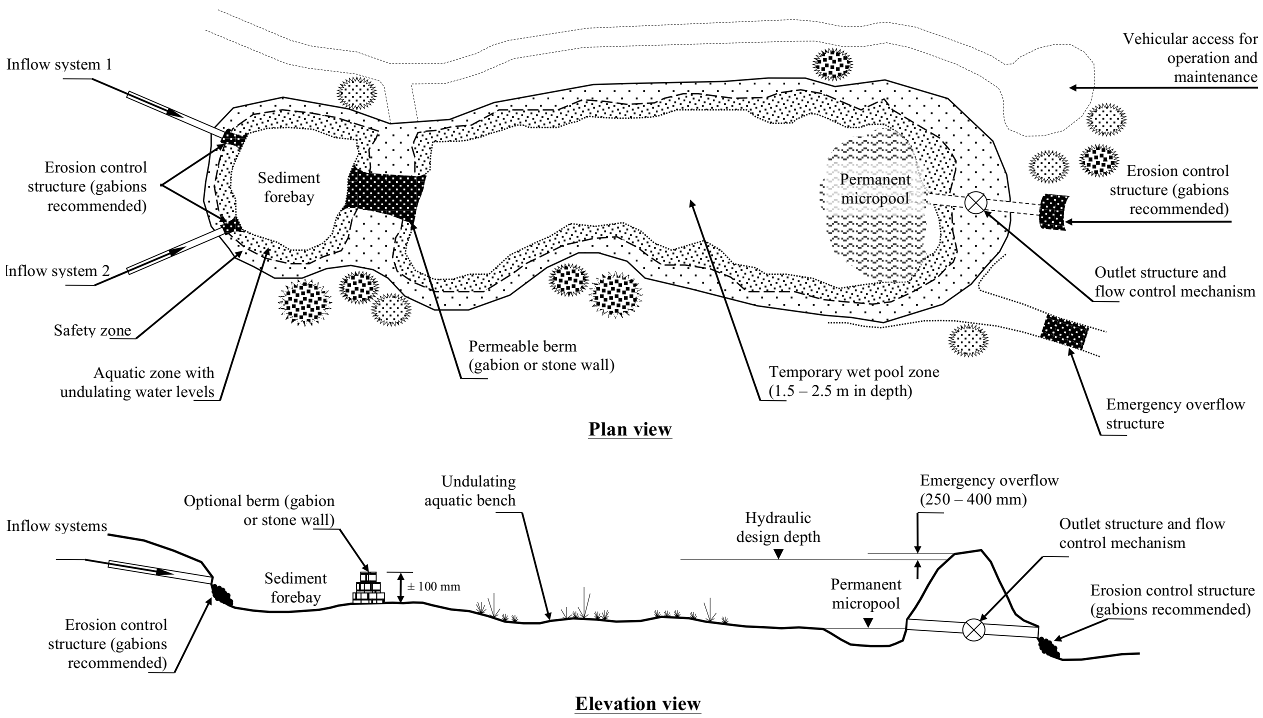
To ensure that all events – from the smallest to the largest – are managed, a 300 mm thick gravel layer should be constructed at the bottom of a dry pond. This will provide storage while the shallow water infiltrates into the subgrade, without exposing the water surface. If the subgrade is impermeable, a very low capacity subsurface drain should be provided.

Inflow hydrographs can be obtained from catchment modelling. Care should be taken when using the Rational Method to estimate the volume (with the duration of the runoff equal to three times the time of concentration), as this gives excessive values for small, relatively impervious catchments (i.e. with a high runoff coefficient). The method only works for larger catchments with lower runoff coefficients. A duration of runoff equal to twice the time of concentration should rather be used, as this does not violate the law of conservation of mass.

Outflow hydrographs are calculated by reservoir (level pool) routing, dependent on the stage/storage and stage/discharge characteristics of the pond. Detention ponds therefore require specially designed outlets to control the discharge and frequently emergency spillways are required to accommodate overtopping.

Other facilities, such as parking areas, sports fields, and areas upstream of road embankments can be designed to provide stormwater detention in an emergency.

Typical detention pond design arrangements are shown in Figure L.19.



Acknowledgement: Armitage et al.[79]

Figure L.19: Typical design for stormwater detention ponds

Retention ponds

Retention systems can be combined with stormwater detention systems by providing for storage above the full supply level (FSL) of the retention pond. The following should be considered when designing retention ponds:

- The local catchment hydraulics and hydrology
- The possible use of floating islands
- The implementation of appropriate safety structures, including disease vector controls
- The prevention of dangerously steep ground slopes around the pond perimeter
- The prevention of erosion at the inlet

To effectively determine the parameters of such a facility, the design inflow hydrographs should be routed through the storage in the basin and outlet system to determine the outflow hydrographs. In this way, downstream effects can be evaluated. Typical design data will include the following:

- The relevant hydrographs for each of a range of design flood recurrence intervals or frequencies, taking cognisance of the ultimate possible post-development characteristics of the catchment (the event that yields the highest outflow peak will have a storm duration longer than that which yields the highest inflow peak)
- Details of the storage and stage characteristics of the detention basin
- Details of the outlet structures with reference to the discharges from the structures at the various stages
- Structural and geotechnical details of the dam wall (type of wall, materials, filters, founding details, spillway structure, protection against erosion and freeboard)
- Safety precautions related to floods and other hazards

- Possible recreational use of the facility
- Maintenance, including sedimentation and maintenance of vegetation

Typical retention pond arrangements are shown in Figure L.20.

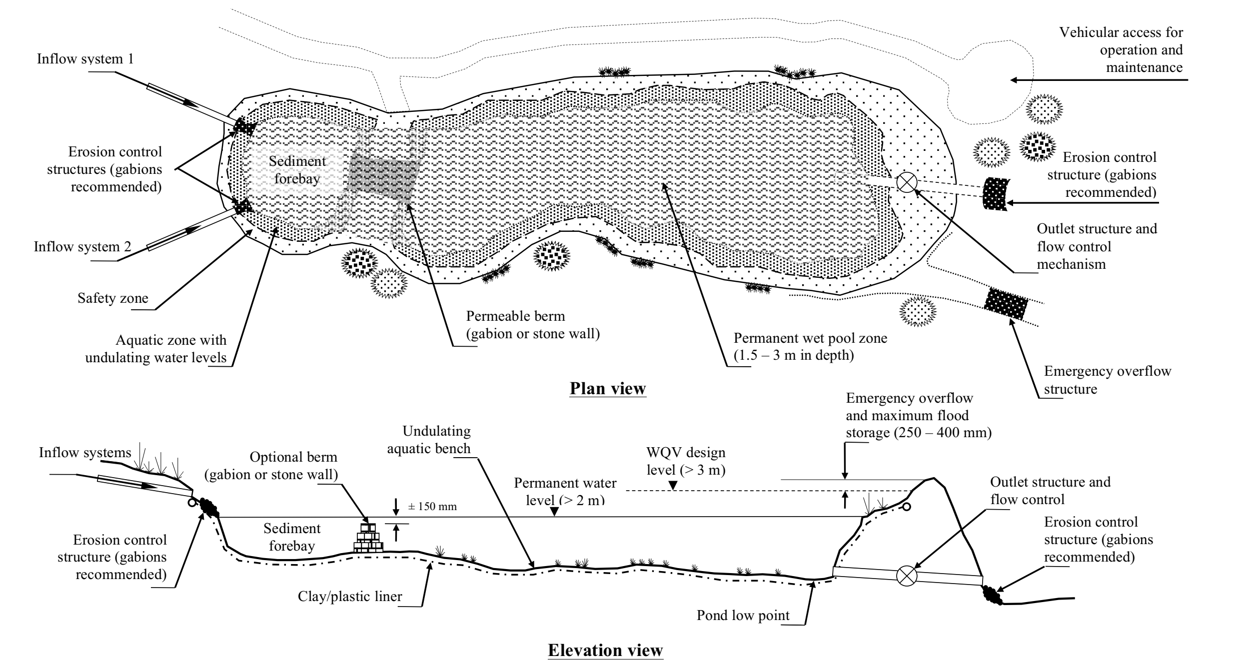


Figure L.20: Typical design for retention ponds

Acknowledgement: Armitage et al. [80]

The dam may need to be registered, classified and evaluated as a 'dam with a safety risk' if it has a wall height greater than 5 m and a capacity exceeding 50 000 m^3. Retention ponds usually have wall heights between 2 and 3 m, which generally do not constitute a safety risk. However, it is imperative that the safety risk of any dam is evaluated. The evaluation process should involve an Approved Professional Person (refer to section 117(a) of the NWA) if the lives of people could be threatened.

Well-designed retention ponds can make provision for stormwater harvesting. Stormwater harvesting yields can be substantially improved through Real-Time Control (RTC). In its simplest form, RTC opens and closes outlet valves in response to water levels in the retention pond – and perhaps others downstream. More sophisticated RTC uses rainfall predictions to regulate the storage in the retention ponds and ensures that the ponds generally remain as full as possible whilst simultaneously containing flood flows through pre-emptive emptying.

Several documents and guidelines[81,82,83,84,85] can be consulted for more information. Software programs are available to design/calculate the flood routing of an inflow hydrograph through a stormwater detention facility to produce the downstream outflow hydrograph.[86,87] Many of these use the storage indication Working Curve Method or Modified Puls Method[88], which is discussed in more detail in Annexure A to this section.

Aquatic weed growth can be reduced in wet (retention) ponds by designing the ponds to have a minimum depth of water of 1 m (after allowing for sedimentation). Aeration of the water may also be necessary to maintain the required quality. The proper design of grids over outlets (limiting the opening to about 300 mm^2) assists in reducing outlet blockages. Reliable emergency spillways that cannot block should be provided. The pollution of ponds can be reduced to some extent by installing grease and sediment traps upstream of the pond inlet. However, reduction or elimination of the pollutants at their source is generally the preferred option.

A common failure of pond embankments is due to piping, either because of poor soils (e.g. dispersive soils), inadequate filter designs, animals that burrow into the embankment, or tree root systems. Legumes should not be used as plant cover for earth embankments as this result in a concentration of nitrogen in the roots, which attracts rodents.

When sports fields are used as stormwater detention facilities, playing surfaces are generally raised slightly above the surrounding area to facilitate drainage and clearing of general debris and siltation. The cysts of pathogenic organisms such as Giardia and Cryptosporidium are common in faecal polluted water and persistent in the environment. The first flush of potentially contaminated water should not be allowed onto fields used for active recreation.

Outlet structures

Various structures can be used to control the outflow from a basin – each with its own advantages and disadvantages. The stage/discharge characteristics of the control, its constructability, ease of maintenance and the possibility of blockage need to be considered in the design. In some instances, aesthetics may be significant, for example the basin and its outlet could be regarded as an urban sculpture.

Where water is discharged to a natural stream, effective energy dissipation is required to prevent erosion of the channel by the jet of water exiting the discharge structure or pipe outlet.

Where water is discharged to a wetland, the outlet structure should be designed to distribute the flow laterally and vertically in the soil profile to emulate the natural pattern of water entering the wetland. One way of doing this would be to construct a French drain at the pipe outlet. The excavation of long 'daylighting' trenches into the wetland is not acceptable.

Constructed wetlands

The following should be considered when designing constructed wetlands:

- Local interest groups, such as nurseries, wildlife and birding associations, should be involved.
- The forebay must protect the macrophyte zone from litter, debris, coarse sediment, and other gross pollutants. Easy access of the forebay should be ensured for maintenance purposes.
- Meandering flow should be created and 'short circuiting' prevented.

The following aspects should be considered in the selection of appropriate vegetation:

- Rapid establishment and growth
- Minimum disease or weed risk
- Suitability for the local climate

- Tolerance of hypertrophic water-logged conditions
- Capacity to remove stormwater runoff pollutants
- Species diversity to provide habitat diversity as well as resilience against disease, and to multiply bioremediation processes

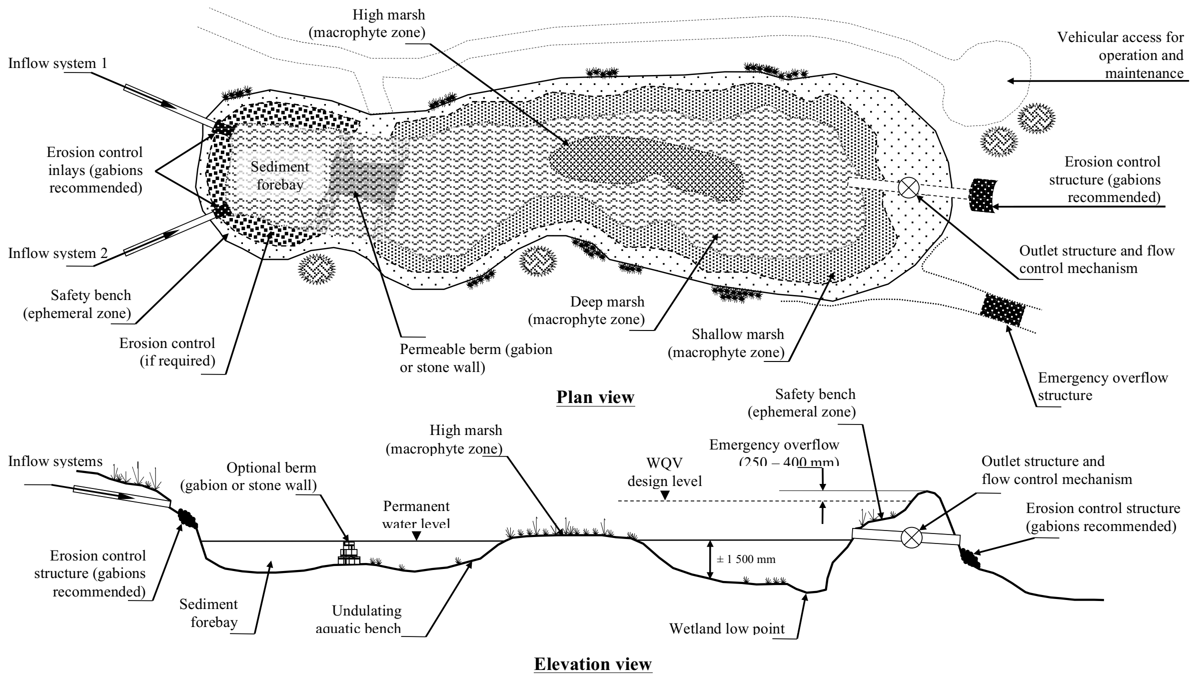
Constructed wetlands typically include the following four zones:

- The inlet zone, which includes a sediment forebay for the removal of coarse sediments
- The macrophyte zone, which is a shallow and heavily vegetated area that facilitates the removal of fine particles and the uptake of soluble nutrients
- The macrophyte outlet zone, which channels cleaner stormwater runoff into adjoining structures downstream
- The high-flow bypass channel, which protects the inlet, outlet and macrophyte zones from vegetation damage and structural scour during periods of abnormally high flow[89]

The principal function of the vegetation in wetlands is to create additional environments for microbial populations. The stems and leaves in the water obstruct flow, facilitate sedimentation, and increase the surface area for the attachment of microbes that constitute thin films of reactive surfaces. Wetland plants also increase the amount of aerobic microbial environment in the substrate. Unlike their terrestrial relatives, wetland plants have specialised structures that enable them to conduct atmospheric gases (including oxygen) down into the roots in waterlogged conditions. This oxygen leaks out of the root hairs, forming an aerobic rhizosphere around every root hair, while the remainder of the subsurface water volume remains anaerobic. This juxtaposition of aerobic/anaerobic environments is crucial to the treatment of nitrogenous compounds and other substances.

- **Microbial organisms:** Microbes (bacteria, fungi, algae, and protozoa) alter contaminant substances to obtain nutrients or energy to complete their life cycles. The effectiveness of wetlands in water purification is dependent on developing and maintaining optimal environmental conditions for the desirable microbial populations. Most of the desirable microbes are ubiquitous and likely to be found in most wastewaters that contain nutrients and energy; hence inoculation of specific strains is generally not necessary.
- **Substrate:** The primary role of the substrate – whether soil, gravel, or sand – is to provide a support for the plants and a surface for attachment by microbial populations. The substrate can also be selected for its chemical characteristics, where pollutant removal is achieved through complexing (a chemical and physical process allowing more complex substances to be formed, which then remain in the substrate zone).[90]
- **Plant selection:** The diversity and complexity of natural wetland vegetation is principally the result of interactions between hydrology, substrate, and climate. If the intention is to mimic a 'natural' wetland, thorough knowledge of local wetland vegetation is a distinct advantage. If, however, the intention is to use the wetland for water purification, several universal species can be used. By far the most commonly used genera are *Phragmites* (the common reed), and *Typha* (referred to locally as the bulrush). Other genera that have been used successfully are various *Scirpus* and *Cyperus* species.

Typical wetland arrangements are shown in Figure L.21.



Acknowledgement: Armitage et al. [91]

Figure L.21: Typical design for constructed wetlands

L.4.2.2 Drainage elements

This section provides design guidance for the drainage elements of the stormwater management system (introduced in Section L.3.3.2).

(i) Simplified Conveyance Design

Channel design

A number of documents that cover channel hydraulic principles[92,93,94,95,96] can be consulted for more information. As a first approximation, steady flows and normal depth conditions are often assumed to determine the channel cross-section that would convey the design flow. Suitable equations for velocity calculation (see Section K.4.3.2) include:

- Manning's formula
- Chezy's equation
- Colebrook-White's equation (substitute 4·R (hydraulic radius) for the diameter D)

Normal flow depth conditions seldom occur in practice, since channel sections are too short or irregular for normal flow depths to be established – thus, gradually varied flow is the norm. Subcritical flow conditions, characterised by large flow depths and low velocities, generally occur upstream of a hydraulic control, whilst supercritical flow conditions, with shallow flow depths and high velocities, occur downstream of a control. Designers must identify the flow conditions and allow for sufficient channel depth to accommodate depths greater than normal flow depth, with allowance for freeboard. Backwater curve calculations can be carried out to determine the variations of water level in gradually varied flow. Backwater curves can be determined by hand (Direct and Standard Step methods) or with computer simulation programs, such as HEC-RAS and DHI Software.

Assuming that normal depth does occur, a first estimate of the depth of flow or the capacity of conduits can be estimated using the Manning equation below.

$$Q = \frac{A^{\frac{5}{3}} \times \sqrt{S_0}}{n \, x \, P^{\frac{2}{3}}}$$

Where:
Q = design peak flow rate (m^3/s)
A = cross-sectional area of flow (m^2)
S_0 = slope of water surface (m/m)
P = wetted perimeter (m)n = Manning roughness coefficient ($s/m^{1/3}$)

Portal and pipe culverts

Culvert design techniques are well established and a number of documents give information on selection and hydraulic design of culverts.[97,98,99] Nomographs could be used with circumspection as they relate to specific design conditions, using basic hydraulic principles.[100] Some municipalities and provincial governments have their own design guidelines regarding flow through culverts.

- **Types and velocities:** Flow types through culverts are categorised according to inlet control, barrel control, or outlet control. The greatest calculated damming height at the culvert inlet is accepted as representing the controlling flow level for the specific flow rate.

  Flow velocities through a culvert should be above 1 m/s to prevent siltation. The potential for scouring at the culvert exit should be examined. If necessary, the flow velocity should be reduced by means of energy dissipaters.

- **Debris and boulders:** Debris and/or boulders can significantly reduce the flow capacity of a culvert, or they may cause forces that threaten the integrity of the structure. Either the culvert should be large enough to allow the flow to pass undisturbed, or debris grids should be provided upstream of the culvert.

- **Culvert transitions:** Culvert transitions are structures that attempt to converge wide, shallow subcritical flows into high-velocity critical flows that can be passed through deep, narrow throats that are more cheaply constructed as culverts or bridges. Sometimes termed minimum energy or maximum discharge designs, this concept allows large flows to be routed through smaller, more efficient and economical culverts or bridges without the usual backwater or headwater required to provide the energy necessary to pass the flow through a typical opening.[101] Consideration must be given to the immediate downstream effects and energy dissipation.

  Modification of the headwall and culvert opening details to conventional culverts and bridges can also reduce the energy loss at the entrance. This lends itself to a more efficient hydraulic design.[102] However, a more efficient hydraulic design through the culvert structure generally leads to higher-energy waters at the outlet. Energy dissipaters may have to be incorporated into the design. Careful design of these structures is required to ensure that they function efficiently through the entire range of expected discharges.

- **Barriers to fish movement:** Culverts with homogeneous high-velocity flow conditions (e.g. greater than or equal to 3 m/s) during flood or spate flow conditions are significant barriers to the upstream migration of fish. Suitable refuges should be constructed at intervals of 3 m to 5 m in the culverts closest to the stream banks. These refuges should provide quiescent flow conditions where fish can rest before setting off upstream with the next burst of high speed swimming. The dimensions and spacing of these refuges will depend on the fish species in the area. Expert advice should be sought in the design of all culverts on watercourses where fish may exist.

Grass-lined channels

The vegetative cover type determines the level of protection against erosion. The grass selected should be easy to establish, drought tolerant, have a low nutrient requirement, a low long-term growth rate and inhibit weed invasion, as well as be capable of withstanding periods of inundation. The basin/channel should drain within 72 hours of a storm event to prevent the breeding of mosquitoes.

The effectiveness of the grass cover also depends on the type of soil, the quality of the cover and the duration of the flow.[103] The permissible flow velocity for soil with a grass cover must be limited to a maximum of 1.3 times the allowable velocity for unprotected soil. The design flow velocity of the grass-lined channel is decided upon by comparing the permissible maximum flow velocity for the specific grass cover and the permissible flow velocity for soil with grass cover.

The side slopes of grass-lined channels should not be steeper than 1:4 (V:H) for maintenance purposes, and they should never be steeper than 1:3, so that persons do not plunge suddenly into deep water. Plastic or fibre netting could be used to reinforce the grass side slopes. 3D plastic meshes are, however, death traps for small reptiles and should be avoided.

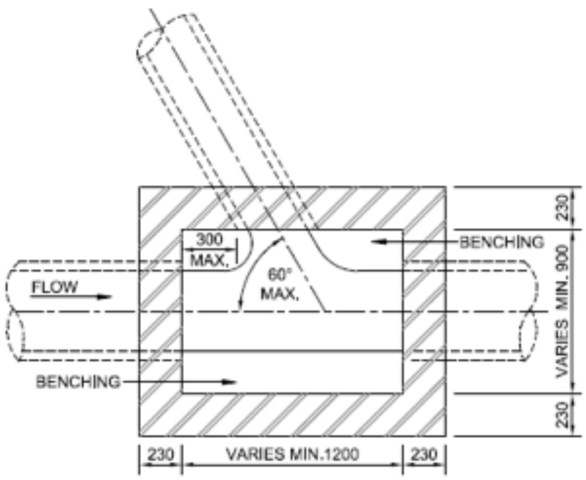
Where flow conditions make grass lining ineffective, loose rock riprap with soil-filled voids is an environmentally acceptable alternative lining. Loose rock riprap is preferred to grouted riprap because it retains the connection between the groundwater and the surface water in the channel and can support vegetation growth. The grading of the riprap will be determined by the bed shear applied by the flowing water, and by uncertainties such as turbulence caused by changes in direction of flow. Design guidance can be found in HEC-11.[104]

Kerb inlets and junction boxes

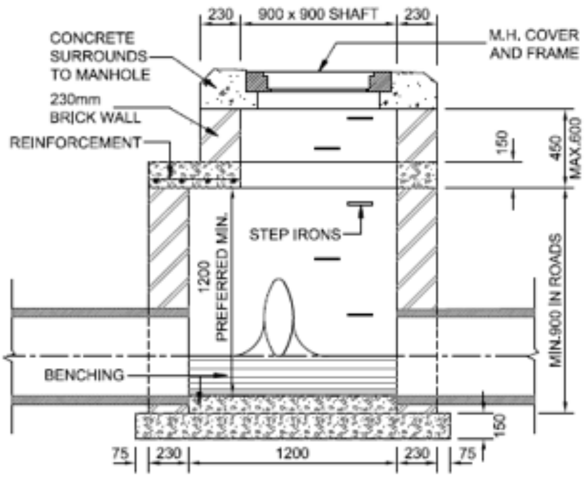
The standards used by municipalities for kerb inlets vary considerably. Generally, the following should be considered:

- Hydraulic performance
- Accessibility for cleaning purposes
- Ability of the cover slabs to bear heavy traffic loads
- Safety for all road users
- Cost

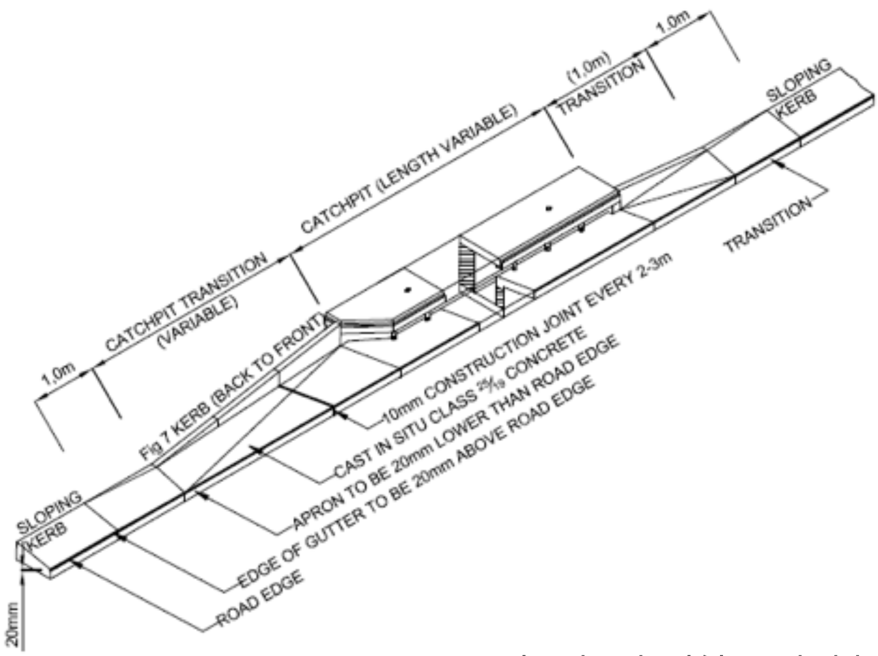
Refer to the literature for guidance in the design of inlets with depressed gutters[105] and in the design of kerb inlets with transitions[106], including the Pretoria-type outlet, which has been widely used. About 20% allowance in capacity must be made for potential blockage.



Typical plan section through junction box



Section through shallow manhole with shaft



Typical catchpit detail (sloping kerb both sides)

Figure L.22: Typical detail of kerb inlets and junction boxes

Acknowledgement: SANRAL Drainage Manual[107]

Road drainage

- **Channel flow:** Manning's formula is the most common method used to determine kerb and channel capacity. Different forms of Manning's equation, modified for specific channel shapes[108], are presented in the literature, but it is recommended here that the basic form of the equation be used and that the variables 'area' (*A*) and 'wetted perimeter' (*P*) be calculated from the conduit geometry.
- **Flow in traffic lanes:** Table L.9 presents the suggested maximum encroachment of runoff on roads during minor storms.

Table L.9: Suggested maximum encroachment of runoff on roads during minor storms	
Road classification	**Maximum encroachment**
Residential and lower-order roads	No kerb overtopping * Flow may spread to crown of road
Residential access collector	No kerb overtopping * Flow spread must leave at least one traffic lane free of water
Local distributor	No kerb overtopping * Flow spread must leave at least one lane free in each direction
Higher-order roads	No encroachment is allowed on any traffic lane

* Where no kerb exists, encroachment should not extend over property boundaries.

- **Encroachment on roads by runoff**
    - **Major storm events**: The encroachment by runoff from a major storm event onto primary roads should not exceed a depth of 150 mm at the crown of the road. This will allow access by emergency vehicles.
    - **Minor storm events:** The suggested maximum encroachment on roads by runoff from minor storms is given in Table L.9.

- **Road gradients**
    - **Maximum road gradients:** The maximum road gradient should be such that the velocity of runoff flowing in the road edge channels does not result in a specific energy of flow of Es> 0.6 m. Where the velocity of flow exceeds this value, design measures should be incorporated to dissipate the energy.
    - **Minimum road gradients:** The minimum gradient for road edge channels should be not less than 0,4% (to reduce deposition of sediment).
    - **Maximum road crown slope:** The maximum slope from the crown of the road to the road edge channel is not governed by stormwater requirements.
    - **Minimum road crown slope:** The minimum slope from the road crown to the channel should be not less than 2% for a plain surface or an average of 2% where the surface has a variable cross slope.
    - **Maximum flow depth:** The depth of flow during a 1:5-year storm should not exceed 6 mm at the crown of the roadway in order to minimise the potential risk of hydroplaning.

Minimum pipe diameters

To ensure pipes are unlikely to block with debris, the minimum pipe diameters for conventional systems should be as follows:

- 600 mm in a servitude
- 450 mm in a road reserve

Minimum velocities and gradients in pipes

The average velocity needs to be above a certain threshold for at least 0.5 hour twice a year to ensure scouring of deposited material. The critical bed shear model indicates that the shear stress of the water on a boundary is related to the velocity gradient at the boundary of the pipe, which means that the deeper the water, the higher the required velocity to reach the required shear force for scouring. As a rule of thumb, the capacity should be designed with a minimum velocity in the range of 0.9 – 1.5 m/s at 100% full uniform design flow for storms of relatively frequent recurrence intervals (two years), but this should be tested against the criterion above. Lower velocities during low flow will not prevent siltation; therefore, maintenance of pipe networks needs to be considered at the design stage.

Table L.10: Suggested minimum grades for pipes[109]

Pipe diameter (mm)	Desirable minimum gradient (1 in ...)	Absolute minimum gradient (1 in...)
300	80	230
375	110	300
450	140	400
525	170	500
600	200	600
675	240	700
750	280	800
825	320	900
900	350	1 000
1 050	440	1 250
1 200	520	1 500

Anchor blocks

Concrete anchor blocks (20 MPa concrete strength) should be provided to eliminate any chance of joint movement on steep gradients, as shown in Table L.11.

Table L.11: Suggested spacing of anchor blocks[110]

Gradient (1 in...)	Spacing for 2.44 m pipe lengths
2 (50%)	Every joint
2 – 3.33 (50% - 30%)	Alternate joints
5 (20%)	Every 4th joint
10 (10%)	Every 8th joint

NOTE: Steep pipes with gradients exceeding a slope of 1:5 are not recommended, due to the very high flow velocities that will result. Drop structures should be considered to reduce slopes.

L.4.2.3 Control structures

This section provides design guidance for control structures that form part of stormwater management systems (see Section L.3.3.2).

(i) Orifices

An orifice outlet where $Q \alpha H^{0.5}$ makes the most efficient use of available storage. Orifices may be any shape, but circular or rectangular openings are easiest to construct. When unsubmerged, i.e. when H/D < 1.2 to 1.5, an orifice will act as a weir.

$$Q = C_d \times A \times \sqrt{2g \times (H - C_h \times D)}$$

Where:

Q = discharge rate (m^3/s)

C_d = discharge coefficient in the range 0.6 to 0.9 depending on the shape of the orifice

A = cross-sectional area of the opening (m^2)

H = depth of water measured from the bottom of the opening (m)

C_h = contraction coefficient[111, 112]

D = opening height (m)

(ii) Weirs

Weirs are divided into two broad categories: transverse weirs where the crest is aligned perpendicular to the direction of approach flow, and longitudinal weirs where the crest is aligned parallel to the direction of approach flow. Typical transverse weirs include the following:

- Unsubmerged orifices
- Broad-crested weirs
  - Rectangular
  - Triangular
- Sharp-crested weirs
  - Rectangular
  - V-Notch
  - Cipoletti weir
  - Proportional or Sutro weir
- Parshall flume
- Spillway crests
- Multi-stage outlet structures

The discharge equation of a weir is:

Q = Coefficient x breadth x head ^ exponent

The shape of the crest and its end conditions determine the coefficient of the discharge equation and the relationship between width, while the head determines the value of the exponent. The discharge characteristics of weirs are well covered in the available literature.[113] All weirs with a level crest of constant breadth will have the same exponent and their discharge equation will have the form:

$$Q = C \times L \times H^{\frac{3}{2}}$$

Where:

Q = Discharge [m^3/s]

C = Discharge coefficient, typically in the range 1.5 to 1.8

C = $C_d \times \frac{2}{3} \times \sqrt{2g}$

C_d = Contraction coefficient, depending on the shape of the weir crest and the ratio of the depth of approach flow to the height of water above the weir crest (a typical value of C_d is about 0.61, but see **Annexure B** for more information)

L = Length of the weir crest transverse to the direction of flow

H = Energy head above the level of the weir crest (for reservoirs or ponds, the energy head is equal to the depth of water)

Weirs can have many different crest shapes. The shape of the crest in the direction of flow affects the discharge coefficient (C_d), whereas the shape of the crest transverse to the direction of flow affects the exponent. A number of documents give information on the selection and hydraulic design of weirs[114, 115, 115, 117, 118]. See **Annexure B** for more information on different weir crest shapes.

The crest of a side weir is parallel to the direction of flow, such as a kerb inlet diverting gutter flow from a road into the underground drainage system. In stormwater management, the principal use of a side weir is to bypass flow up to some value, after which increasing amounts are diverted. An example of this is where a dry, offline basin is used to 'clip' the top off a flood hydrograph. The discharge characteristics can be complex as the magnitude, and hence the depth, of the approach flow varies along the length of the weir. More information is available internationally.[119]

L.4.2.4 Outfall management

Outfall management (see **Section L.3.3.2**) is largely a function of the receiving system, which could range from minimal to no intervention required (outfall to a concrete-lined channel), moderate intervention required (outfall to a river) and complex integrated measures required (outfall into a wetland).

The governing authority's standard should be adhered to as a minimum, but the flow from the outfall should never damage the receiving system. A rule of thumb is to limit the velocity of discharge from an outlet structure to less than 1 m/s and the depth to 100 mm. If the design indicates that this condition will be exceeded, additional energy dissipation measures may be required. The discharge should mimic the characteristics of the natural system, for example, if a wetland naturally receives distributed surface and subsurface flow, then the stormwater management design should ensure that the inflow has similar characteristics.

(i) Protection against erosion

Swales

Swales are generally a cost-effective way to convey stormwater. The use of indigenous plants for stabilisation is recommended. Velocity of water flowing in the waterway should be limited in relation to the erodibility and slope of the waterway. Planting used for protection against erosion should meet the following requirements:

- Cover the ground surface as densely as possible – lawn-forming grasses can be combined with forbs or tussock-forming grasses to achieve this
- Be sufficiently robust and dense to provide the hydraulic resistance required
- Be sufficiently deep rooted to resist the hydraulic forces imposed on them
- Be hardy and able to thrive in the harsh environmental conditions that are likely to occur (locally indigenous plants are preferred)
- Protect the ground surface from the impact of raindrops
- Be visually attractive and diverse
- Be ecologically and structurally diverse to enhance habitat diversity

Fencing

Fencing off the waterway in an environment where rural or urban agriculture can be expected is usually an effective way of controlling livestock until the grass cover has been established. Once a grass cover has been established, livestock can be introduced onto the grassed waterway in a controlled manner.

African ecosystems have evolved to tolerate and rely on trampling by herd animals. Access by livestock should be managed to mimic this condition if locally indigenous vegetation is used to protect the swale.

(ii) Energy dissipaters

The purpose of energy dissipaters is to reduce the energy in the flow discharging from the outfall to a level that will not damage the receiving system. Most energy dissipaters work by forcing a sudden expansion in the flow, either by creating a hydraulic jump or by discharging the flow into a plunge pool.

The size and type of an energy dissipation system will depend on the scale. The energy of water discharging from small- to medium-sized pipes can effectively be dissipated in preformed scour holes or riprap aprons. Large pipes and culverts will require more elaborate and robust energy dissipation structures. The following should be considered when designing energy dissipaters:

- Widen the drainage way and decrease the depth of flow. This will have the effect of reducing the velocity of flow. Overland flow is a typical example. Supercritical flow does not expand easily, so careful design will be required to force the streamlines to diverge.
- Increase the roughness of the canal or drainage way. Although this will increase the total cross-sectional area of flow, it will decrease the velocity. Roughness elements must be designed to resist the shear and drag forces imposed on them.

Structures for energy dissipation include the following:

- Roughness elements
- USBR type II basin
- USBR type III basin
- USBR type IV basin
- SAF stilling basin
- Contra Costa energy dissipater
- Hook-type energy dissipater
- Trapezoidal stilling basin
- Impact-type energy dissipater
- USFS metal impact energy dissipater
- Drop structures
- Corps of Engineers stilling well
- Riprap basins

A number of documents[120, 121, 122] provide information on the selection and hydraulic design of energy dissipation structures.

(iii) Structural elements

The *SANRAL Drainage Manual*[123] gives design guidelines on various protective linings.

The structural elements that are typically used include the following:

- Geocells
- Geotextiles
- Geomembranes
- Riprap
- Gabions (refer to *SABS 1200 Standardised Specification for Civil Engineering construction*[124])
- Reno mattresses (refer to *SABS 1200*[125])
- Linings
- Stone pitching (refer to *SABS 1200*[126])
- Concrete
- Grass linings

The stability of lining materials can be determined by comparing the shear stress applied by the flowing water to the stream bed with the critical shear required to move the particles of the bed material. The critical shear is a function of particle size and specific gravity, while the bed shear is a function of the energy slope and depth of the flowing water.

The shape of some proprietary products also induces uplift, which should be included in the stability analysis.

Wiring may not enhance the local stability of concrete block products. It should be determined how much the block must move before stabilising forces applied by the wires become effective.

In a lined channel, the flow between the lining and the subgrade will have the same energy gradient as the flow in the channel. This flowing water can cause the migration of fine material from underneath the lining material. Care should be taken to ensure that the protective layers are not undermined by providing filter material. Geofabric filters are often ineffective because it is not possible to eliminate all voids between the fabric and the subgrade, and these voids can provide preferential flow paths that result in erosion of the subgrade. Graded filters comprising successive layers of adequate thickness and appropriate material size are preferred. Refer to the *SANRAL Drainage Manual*[127] for design guidelines for granular filter materials.

The effective roughness of grassed linings varies with the velocity of the flowing water, and the resistance of the lining to erosion is a function of the velocity and duration of flow. A number of documents give information on the selection of the effective roughness of grass linings[128, 129].

What is riprap?

Riprap is a heavy stone facing on a shore bank or stream bed used to protect it and the adjacent upland against wave scour and erosion by flowing water. Riprap depends on the soil beneath it for support and should be built only on stable shores and bank slopes. The grading and thickness of the riprap are dependent on the forces that will be imposed on it. A number of documents give information on the selection and hydraulic design of riprap.[130]

(iv) Environmental health and safety

All designs for stormwater should incorporate elements to achieve the relevant authority's minimum environmental, health and safety standards where relevant, e.g. dam safety, flood-warning systems, and suitable recreational facilities. Technologies available for the design include the following:

Silt fencing and straw bale barriers

Silt fences and hay/straw bale barriers are two types of filter barriers. They are temporary structures that are installed across, or at the toe, of a slope. They are used to control sheet flow and are not effective in areas of concentrated flow, such as ditches or waterways.

Temporary check dams

Small temporary check dams constructed across a ditch or small channel reduce the velocity of concentrated stormwater flows. They also trap small amounts of sediment. Temporary check dams are useful on construction sites, or for temporary stabilisation of erosion areas where protection is required for the establishment of vegetation. Careful design and sizing is required, since overtopping of a check dam can result in erosion of the wall and excessive volumes of sediment being washed downstream.

Other technologies

Geofabrics, matting, netting, mulching and brush layering are other technologies that attempt to protect the soil from rain impact and impede the flow of stormwater runoff. The alternative biological approach is often integrated with the structural technologies. Many of the indigenous flora can be effectively used to form vegetation buffer strips and other natural barriers, sponges and stable riverine corridors.[131]

Street cleaning

Street cleaning, which can be an effective method of removing litter and sand-sized particles, needs to be designed for (refer to Section M.4.1). Overall pollutant removal by street sweeping is not, however, very efficient, with a typical removal of 10% to 30%.[132] Organics and nutrients are not effectively controlled, but regular – daily or twice daily – street cleaning can remove up to 50% of the total solids and heavy metal yields in urban stormwater.[133] It can also be a very effective method of removing litter.

L.4.3 The design of a major system

L.4.3.1 Flood protection

The stormwater management system for all new neighbourhoods (or settlements) should be designed to safely contain floods up to the 1:20-year flood without the flooding of properties, i.e. within the road reserve boundaries. Conditions should also be checked for the 1:100-year event to assess the risk of dwellings' floor levels being inundated. Floor levels should be 300 mm (minimum) above the 1:100 flood levels. For safety of road users, the specific energy ($E_s = h + v^2/2g$) of water flowing in public roadways should not exceed 0.6 m.

The underground pipes of the minor system are sometimes assumed to be flowing full during a major storm event. However, inlets of the minor system are easily blocked by the debris associated with major floods and it is usually assumed that the minor system makes no contribution to the flow. Modern design software allows minor and major drainage systems to be modelled concurrently in the case of floods.

L.4.3.2 Flood lines

The determination of flood lines is usually based on the routing of stormwater through the watercourse (drainage way). The capacity of a channel, whether natural or constructed, is affected by the interaction of local features and the varying flow profile. The routing in a channel has been addressed in different documents and guidelines[134, 135, 136, 137].

Numerous computer programs (such as the HEC-RAS and subsequent updates) are available to aid in the determination of water surface profiles to show flood lines. The HEC-RAS is used most often and is capable of computing one-dimensional steady flow to determine the sub-critical and super-critical water surface profiles by energy balance. It then combines these by using momentum to determine a mixed profile, for example to estimate the positions of hydraulic jumps.

The HEC-RAS has the capability to analyse unsteady flow, such as may arise from a dam failure. The numerical routines used by HEC-RAS have, however, proven to be unstable in some tests, and variations of SWMM may be easier to work with.

In many instances, for example in flooding of urban areas, flow paths are divided and flow changes direction rapidly, thus violating the assumption of one-dimensional flow. Software to model two-dimensional flow for better analysis of these conditions includes inter alia, HEC-RAS 2D, HydroSWMM, PCSWMM 2D, TUFLOW, Mike 21, and Infoworks. Software should be selected based on the physical processes[138] included in the model equations, rather than on the numerical methods used to solve them. Some models can combine 1D and 2D processes, which can simplify model construction and reduce computational overheads.

L.4.3.3 Flood routing and bridge backwaters

Flood routing is based on the continuity equation:

$$Q_{\text{out}} = Q_{\text{in}} - \frac{dS}{dT}$$

Where:

Q_{out} = outflow discharge (rate of flow)

Q_{in} = inflow discharge (rate of flow)

dS/dT = the rate of change of storage within the system

See **Annexure A** for a more detailed description of the flood-routing equation.

While backwater curves at bridges can be calculated by hand, computer software programs such as HEC-RAS and DHI Software can also be used. Consider the detail on the design of bridge waterways[139, 140, 141]. Consideration should be given to the additional backwater effects at bridges near the ocean, due to tidal effects and high sea levels that may be caused by storm surges.

L.4.4 Operation and maintenance considerations

It is of prime importance that the stormwater management system be maintained and operated in accordance with the objectives of the design. Obtaining the cooperation of the public and (in particular) local residents will help ensure the success and optimal use of the system. Education programmes, projects in association with groups such as schools (e.g. 'adopt-a-wetland') and 'Friends' groups should be encouraged. Effective monitoring based on the requirements of an Operation Management Plan is stressed[142]. Maintenance programmes should be initiated and led by national or local authorities (government-led) or by local communities (community-led).

Appropriate operational and maintenance considerations made during the design stage will ease operations and minimise maintenance, which will also promote and enhance water quality in the system. Some maintenance guidance for different stormwater system elements is provided in this section.

(i) Rain gardens

Maintenance of rain gardens should include replanting or pruning, topping up of the mulch layer, and possibly skimming accumulated fine sediment from the surface to restore permeability of the soil.

(ii) Bioswales

To ensure that bioswales function effectively, routine inspection and maintenance should be performed. Maintenance of bioswales should include the repair of any surface erosion, replanting or pruning, topping up of the mulch layer and possibly skimming accumulated fine sediment from the surface to restore permeability of the soil. If the swales receive runoff from roads or other areas that may be sources of heavy metals, the growing medium should be tested from time to time and be removed and replaced if found to be contaminated. Soil contaminated by heavy metals should be disposed of at a properly licenced facility. Compost made from hyper-accumulator plants may be contaminated with metals and should not be returned to the environment, but appropriately disposed of.

(iii) Pond facilities

The nature of a stormwater pond facility depends on its type, function, location, and general environment. Many problems can be avoided by proper design and construction procedures. The control of weed growth and invader plants, and the mowing of lawns are necessary for aesthetic and health (mosquito control) reasons. Table L.12 lists some of the problems commonly experienced with stormwater detention facilities.

Problem	Comments
Weed growth	Easy access to the site will enable the maintenance department to combat weed growth. Designers should establish acceptable pioneer grasses in consultation with a landscape architect.
Maintaining grass	Bank slopes should be gentle enough to allow access by maintenance equipment where banks are grassed.
Sedimentation and urban litter	Site-specific measures are required with the aim of providing a sediment trap upstream of the facility. Urban litter is difficult to remove.[145]
Mosquito control	Regular mowing is required – keeping the grass short facilitates evaporation and provides access for predators of mosquito larvae. Different mosquito species have different breeding strategies. Take specialist advice on the likely species in the project area. Avoid the use of insecticides and oil films.
Outlet blockages	Regular inspection and cleaning are required. Incorporate straw bale filters and trash racks. Control litter. Maintain vegetation.
Soggy surfaces	A gravel layer should be used in the bottom of the basin and a low-capacity subsurface drain be installed if soil infiltration capacity is low.
Inflow water pollution	Regular maintenance of detention facilities during wet season is required. Consider wetland filters at inlets.
Algal growth	Attempts should be made to create a balanced ecology.
Fence maintenance	Fences should be avoided. It is better to design ponds, including wet ponds that are reasonably safe for the public e.g. no vertical walls for kids to fall down.
Unsatisfactory emergency spillway design	Dam design requirements need to be adhered to.
Dam failures and leaks	Dam design requirements (e.g. dispersive soils) need to be adhered to.
Public safety during storm events	Flood-warning systems should be considered where hazard is high.

Table L.12: Problems commonly experienced with detention facilities[143, 144]

(iv) Recreational use of watercourses

Watercourses should be managed and maintained in urban environments. The commitment to maintain these natural corridors should be communicated to all involved and not be the burden of the authorities only. Many campaigns exist to encourage public participation in maintaining natural areas.

(v) River restoration or renaturalisation

Note that stream rehabilitation or renaturalisation is not synonymous with channel lining to stabilise banks or reduce bed erosion. Renaturalisation objectives should be defined and recorded before design geometry and materials are considered. Some rehabilitation measures that could be implemented include the following:

- Protect the channel directly (covering the channel with a lining that is less erodible than the in-situ material) or indirectly (providing obstructions that cause damming to reduce flow velocity, i.e. drop structures) against erosion (see Section L.4.2.4).
- Establish vegetative cover to protect the soil from the erosive power of wind and stormwater runoff (see Section L.4.2.2).
- Clear the area of debris and solid waste.
- Implement runoff water quality treatment measures (see Section L.4.1.4).

Annexure A

Storage indication Working Curve Method or Modified Puls Method

The flood standard routing equation is

$$\left(\frac{I_1 + I_2}{2}\right)\Delta T - \left(\frac{Q_1 + Q_2}{2}\right)\Delta T = S_2 - S_1 = \Delta S$$

This can be transposed to

$$\left(\frac{I_1}{2}\right) + \left(\frac{I_2}{2}\right) + \left(\frac{S_1}{\Delta T}\right) + \left(\frac{Q_1}{2}\right) - Q_1 = \left(\frac{S_2}{\Delta T}\right) + \left(\frac{Q_2}{2}\right)$$

Where:
I_1 and I_2 are the inflow rates at times T_1 and T_2 respectively
Q_1 and Q_2 are the outflow rates at times T_1 and T_2 respectively
S_1 and S_2 are the storage rates at times T_1 and T_2 respectively
ΔT is the time increment between time T_2 and T_1

The Modified Puls Method is performed as follows:

- Use hydrological calculations to obtain an inflow hydrograph for the catchment through which water needs to be routed, using the appropriate outlet structure (e.g. weir or orifice).
- Determine the storage volume (S) for different water levels.
- Determine the head/discharge relationship for the outlet structure (outflow Q).
- Draw a graph showing the relationship between the outflow Q and $(\frac{S}{\Delta T}) + (\frac{Q}{2})$ for a selected timestep ΔT.
- By developing the relationship between Q and $(\frac{S}{\Delta T}) + Q$, Q_2 can be interpolated from the value of $(\frac{S_2}{\Delta T}) + (\frac{Q_2}{2})$ and S_2 can be interpolated from the relationship between Q and S.
- In the next time step the terms Q_2 and $(\frac{S_2}{\Delta T}) + (\frac{Q_2}{2})$ become $Q1$ and $(\frac{S_1}{\Delta T}) + (\frac{Q_1}{2})$ respectively, so that the third storage value and discharge can be deduced, and so on.

Refer to the *SANRAL Drainage Manual*[146] for more information on flood routing.

Annexure B

Weirs

Weirs may have many different crest shapes. The shape of the crest in the direction of flow affects the discharge coefficient (C_d). The shape of the crest transverse to the direction of flow affects the exponent. Transverse rectangular sharp-crested and broad broad-crested weirs are used most commonly.

Sharp-crested weirs

The discharge equation for a sharp-crested weir is:

$$Q = C \times L \times H^{\frac{3}{2}}$$

Where:

Q = Discharge [m^3/s]

C = Discharge coefficient, typically in the range 1.5 to 1.8

C = $C_d \times \frac{2}{3} \times \sqrt{2g}$

C_d = Contraction coefficient, depending on the shape of the weir crest and the ratio of the depth of approach flow to the height of water above the weir crest

L = Length of the weir crest transverse to the direction of flow

H = $h + h_v$ = Energy head above the level of the weir crest (for reservoirs or ponds $V_0 = 0$, so the energy head is equal to the depth of water)

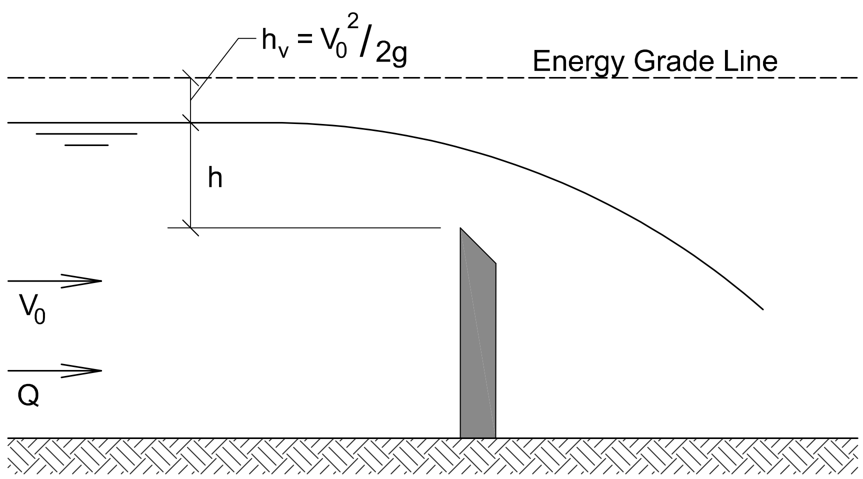


Figure L.B.1: Sharp-crested weir

Broad-crested weirs

A broad-crested weir is where flow becomes critical and stream lines are parallel over the width of the crest. The standard formula for calculating flow over a broad-crested weir is:

$$Q = C \times L \times H^{\frac{3}{2}}$$

Where:
Q = Discharge [m^3/s]
C = Discharge coefficient, typically 1.7
H = $h + h_v$ = Energy head above the level of the weir crest (for reservoirs or ponds $V_0 = 0$, so the energy head is equal to the depth of water above the weir crest)
L = Length of the weir crest

In Figure L.B.2, dc is the critical depth and w the width of the weir.

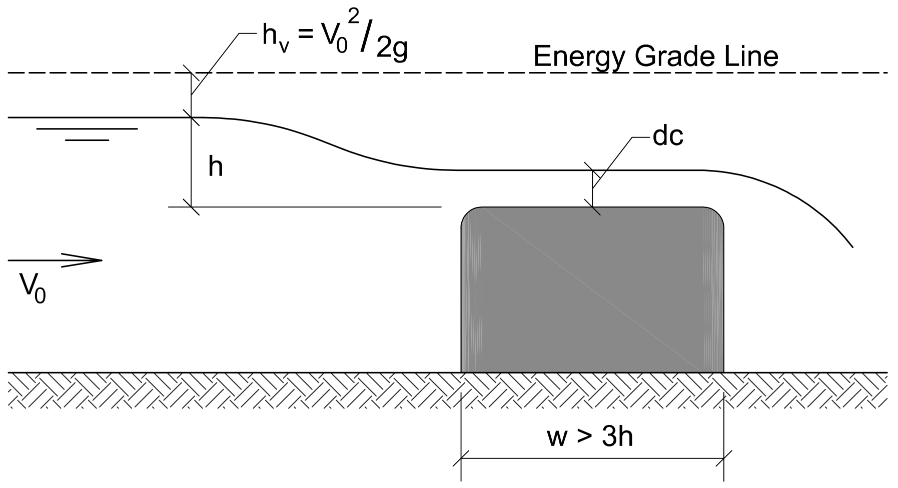


Figure L.B.2: Broad-crested weir

Spillway-crested weirs

Overflow spillway crests are widely used as outlets from stormwater detention facilities. Guidelines are available for the design[147].

Trapezoidal weirs

The stage/discharge equation of trapezoidal weirs with a level crest and sloping ends has a compound form with the exponent of the level part equal to 3/2 and the exponent of the sloping part equal to 5/2. A special form of the trapezoidal weir is the Cipoletti Weir, where the ends slope at 1:4 (H:V) and the coefficient of the equation is corrected to account for the increasing width – in other words the exponent remains constant at 3/2.

Proportional weirs

The proportional weir has a linear head-discharge relationship, i.e. the value of the exponent in the discharge equation is unity. Two forms of the proportional weir are summarised below, i.e. the improved inverted V-notch weir with straight sides and the Sutro weir with curved sides.

- **The Sutro weir**

The relationships for a Sutro weir are as follows:

$$Q = C_D \times \sqrt{2ga} \times b \times (h - \tfrac{a}{3})$$

and

$$\tfrac{x}{b} = 1 - \tfrac{2}{\pi} \times tan^{-1} \left(\sqrt{\tfrac{y}{a}}\right)$$

Where:
Q = the flow in m^3/s
C_D = the discharge coefficient, assumed to be approximately 0.62
a, b, h, x and y are given in metres

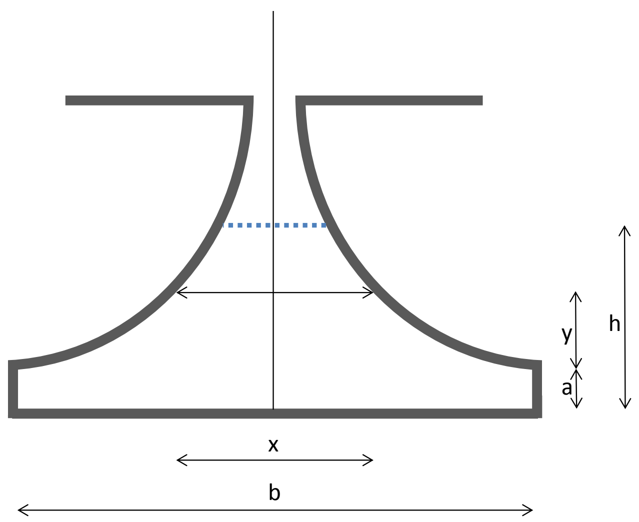


Figure L.B.3: Sutro weir

- **The Improved inverted V-notch or chimney weir**

For flows through this weir over a depth of 0.22d but less than 0.94d (where d is the V-sloped section height) – discharges are proportional to the depth of flow[148]. See Figure L.B.4.

$$q = \frac{2}{3} \times C_D \times \sqrt{2g} \times 2 \times W \times h^{\frac{3}{2}} - \frac{8}{15} \times C_D \times \sqrt{2g} \times tan\ \theta \times h^{\frac{5}{2}}$$

for $O < h < d$

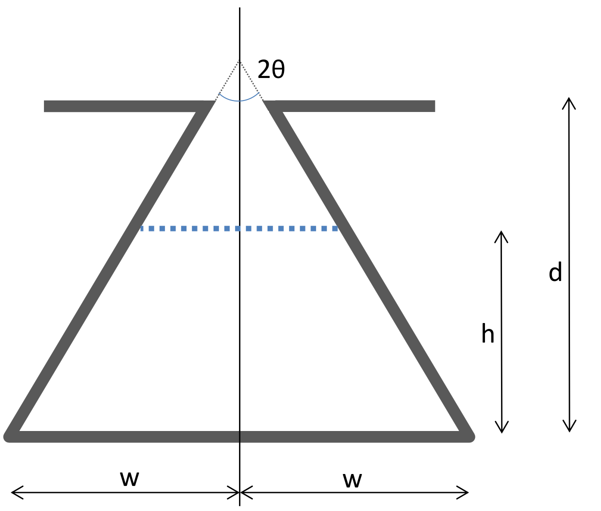


Figure L.B.4: Inverted V-notch or chimney weir

Side weirs

Side weirs are structures often used for irrigation, sewer networks and flood protection, for example a kerb inlet.[149, 150] Side weirs can be used to divert peak discharges from a channel into a management pond, while allowing base flow or spate flow to bypass the diversion. Hydraulic design of side weirs can be complex if the channel water surface profile changes significantly along the length of the weir[151].

Glossary, acronyms, abbreviations

Glossary

Bioretention area
A depressed landscaped area that collects stormwater runoff and infiltrates it into the soil below through the root zone, thus prompting pollutant removal.

Bioswale
A planted depression that receives stormwater runoff from impervious areas and from less pervious vegetated areas such as compacted lawns. It drains this water away by slow surface and subsurface flow, while giving the water an opportunity to soak into the ground.

Catchment
The area contributing runoff to any specific point on a watercourse or wetland.

Channel
Any natural or artificial watercourse.

Conveyance
The transfer of stormwater runoff from one location to another.

Channel protection volume
The volume and rate of flow required for management to reduce the potential for degradation in natural channels. It is usually achieved through the detention of runoff on site. The critical storm event typically has a recurrence interval of around two years.

Culvert
A structure made from reinforced concrete or other material, which is used for stormwater conveyance.

Detention pond
A pond that is normally dry except following large storm events when it temporarily stores stormwater to attenuate flows. It may also allow infiltration of stormwater into the ground.

Don't Do Damage
The importance of ensuring that extreme storm events do not cause significant damage to property or pose significant risks to life.

Drainage area
An area that is part of a catchment that contributes to the runoff at a specified point.

FC_d – Flow control (major storms)
The reduction of peak storm flow rate (m^3/s) to the equivalent of the pre-development scenario (or accepted alternative), while simultaneously ensuring that risks to property and human life are mitigated. This is typically used for storm events with a recurrence interval greater than 10 years.

FC_m – Flow control (minor storms)
The reduction of peak storm flow rate (m3/s) to the equivalent of the pre-development scenario. This is typically used for storm events with a recurrence interval of between 2 and 10 years.

Filter strip
Maintained grassed areas of land that are used to manage shallow overland stormwater runoff through several filtration processes.

Filtration
Also referred to as biofiltration, means the filtering out of stormwater runoff pollutants that are conveyed with sediment by trapping these constituents on vegetative species in the soil matrix or on geotextiles.

Flood
A temporary rise in water level, including groundwater or overflow of water, onto land not normally covered by water.

Flood plain
The area susceptible to inundation by floodwater escaping from a natural or constructed waterway.

Gabion
A rectangular-shaped steel wire basket that is generally filled with rock for embankment protection and flood control.

Geotextile
A textile or plastic fabric designed to separate different fill materials. It is normally permeable.

Green roof
A roof on which plants and vegetation can grow. The vegetated surface provides a degree of retention, attenuation, temperature insulation and treatment of rainwater.

Hydrology and hydraulics
The design of drainage structures is based on the sciences of hydrology and hydraulics. The former deals with the occurrence and form of water in the natural environment (precipitation, streamflow, soil moisture, etc.), while the latter deals with the engineering properties of fluids in motion.

Infiltration
The process of penetration of rainwater into the ground.

Infiltration trench
A trench that is usually filled with granular material designed to promote infiltration of surface water into the ground.

Local control
Interventions to manage stormwater runoff typically in public areas such as road reserves or parks.

Major system
A stormwater drainage system that caters for severe, infrequent storm events. Design criteria are primarily based on safety. The major system is supported by the minor drainage system.

Minor system
A stormwater drainage system that caters for frequent storms of a minor nature. Design criteria are primarily based on convenience.

Nomograph
A chart or graph from which, given a set of parameters, other dependent parameters can be ascertained.

Peak discharge
The maximum rate of flow of water passing a given point during or immediately after a rainfall event (also known as 'peak flow').

Permeability
The ability of a material to allow water to flow through when fully saturated and subjected to an unbalanced pressure.

Rain garden
A planted depression that receives stormwater runoff from impervious areas and less pervious vegetated areas such as compacted lawns, giving this water an opportunity to soak into the ground.

Rainwater harvesting
The direct capture of stormwater runoff, typically from rooftops, for supplementary water uses on site.

Recharge volume
Recharge volume (ReV) is the proportion of the Water Quality Volume (WQV) that needs to be infiltrated on site to make up for the reduction of natural infiltration.

Recurrence interval
The Recurrence Interval (RI) is the average interval between events exceeding a stated benchmark (also known as return period). The recurrence interval is usually expressed in years and is the reciprocal of the annual exceedance probability (AEP) – for example, the event having an annual probability of occurrence of 2% (0.02) has a recurrence interval of 50 years. This does not imply that such an event will occur after every 50 years, or even that there will necessarily be one such event in every 50 years, but rather that over a very long period (e.g. 1000 years), assuming no climate change, there will be approximately 20 events of greater magnitude (1000/20 = 50 years).

Regional Maximum Flood
An empirically established upper limit of flood peaks that can be reasonably expected at a given site.

Regional control
A large-scale intervention used to manage stormwater runoff on municipal land.

Reno mattress
A rectangular-shaped steel wire basket that is generally filled with rock for embankment protection and flood control.

Retention pond
A basin where runoff is retained for a sufficient time to allow settlement of solids and possibly biological treatment of some pollutants.

Runoff
The water that constitutes streamflow may reach the stream channel by any of several paths from the point where it first reaches the earth as precipitation. Water that flows over the soil surface is described as surface runoff and reaches the stream soon after its generation as rainfall. Other water infiltrates through the soil surface and flows beneath the surface to the stream.

Sand filter
Normally comprises a sedimentation chamber linked to an underground filtration chamber containing sand or other filter media through which stormwater flows.

Sheet flow
Runoff over a relatively flat or flattened surface. It has no defined channel.

Soakaway
A subsurface structure that is designed to promote infiltration into the ground.

Source control
Non-structural or structural management practice to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source.

Spillway
A waterway adjoining ponding areas or other hydraulic structures used for the routing of excess water.

Swale
A shallow vegetated channel designed to convey stormwater, but may also permit infiltration. The vegetation assists in filtering particulate matter.

Weir
A relatively small dam-type structure across a waterway used to divert flow, reduce erosion and/or measure flow volumes.

Wetland
Any land translational between terrestrial and aquatic systems where the water table is usually at or near the surface; which is periodically covered with shallow water, and which in normal circumstances supports or would support vegetation typically adapted to live in saturated soil. This includes water bodies such as lakes, salt marshes, coastal lakes, estuaries, marshes, swamps, vleis, pools, ponds, pans and artificial impoundments.

Water Quality Volume
The design volume of runoff that requires water quality treatment to reduce/remove a specified percentage of pollutants.

Acronyms and abbreviations

CPV	Channel protection volume
D3	Don't Do Damage
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
IWRM	Integrated Water Resource Management
NHBRC	National Home Builders Registration Council
NWA	National Water Act
PMF	Probable Maximum Flood
ReV	Recharge Volume
RI	Recurrence Interval
RMF	Regional Maximum Flood
RTC	Real-time Control
SABS	South African Bureau of Standards
SANRAL	South African National Roads Agency Limited
SANS	South African National Standards
SCS	Soil Conservation Services
SDF	Standard Design Flood
SS	Suspended Solids
SuDS	Sustainable Drainage System
TP	Total Phosphorus
WQV	Water Quality Volume
WRC	Water Research Commission
WSD	Water Sensitive Design
WSUD	Water Sensitive Urban Design

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Section M
Solid waste management

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 M

Solid waste management

The Neighbourhood Planning and Design Guide

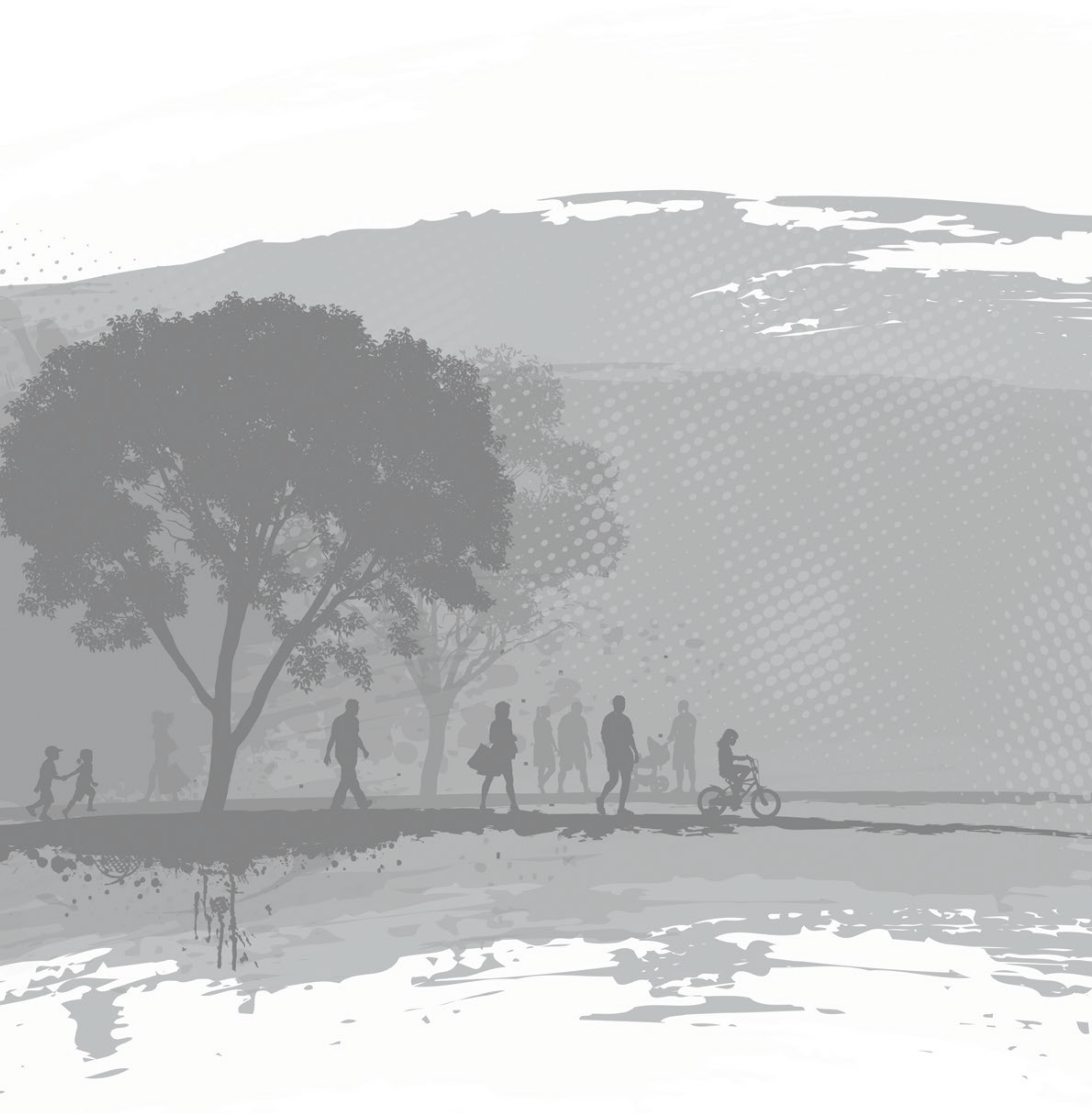


Table of contents

M.1 Outline of this section

M.1.1 Purpose

Settlements (and neighbourhoods as the 'building blocks' of settlements) are integrated systems in which the various components are interconnected, and this section highlights the role of solid waste management in this system. Urbanisation, population growth, economic growth and accompanying lifestyle changes result in the use of more consumer products and consequently the generation of more waste. The additional waste that is generated has wide-ranging impacts on settlements: it puts additional pressure on municipal service delivery and on landfill sites, it may result in the pollution of soil, air and water resources, and it can have negative public health implications. Sound solid waste management practices and the appropriate and efficient storage, collection, transport, treatment and disposal of waste can potentially prevent or mitigate these impacts.

The National Environmental Management: Waste Act, 2008 (NEM:WA) as amended and the National Water Act, 1998 provide legal definitions for waste. In the context of this Guide, waste refers to solid materials, substances or objects that are unwanted, rejected, abandoned, discarded or disposed of, or that are intended or required to be discarded or disposed of by the holder, irrespective of their value or potential to be reused, recycled or recovered. Waste ceases to be waste once it is reused, recycled or recovered.

Solid waste management differs from most other municipal (engineering) services in a significant way: Communities are not only expected to pay for the waste removal service – they have to take specific actions in order for the waste to be removed, including the sorting of waste and making waste available for collection on the sidewalk or at a communal point. It is therefore critical that waste collection infrastructure and services are responsive to the needs of the communities being served.

This section has a direct link with **Section F** (Neighbourhood layout and structure), **Section I** (Transportation and road pavements) and **Section L** (Stormwater).

M.1.2 Content and structure

This section (Section M) is structured to support effective decision-making related to solid waste management. The decision-making framework is outlined in Figure M.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 solid waste management 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 solid waste management 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 solid waste management that are available for consideration

Design considerations

Guidelines to assist with the design of solid waste management systems and infrastructure.

Glossary, acronyms, abbreviations

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

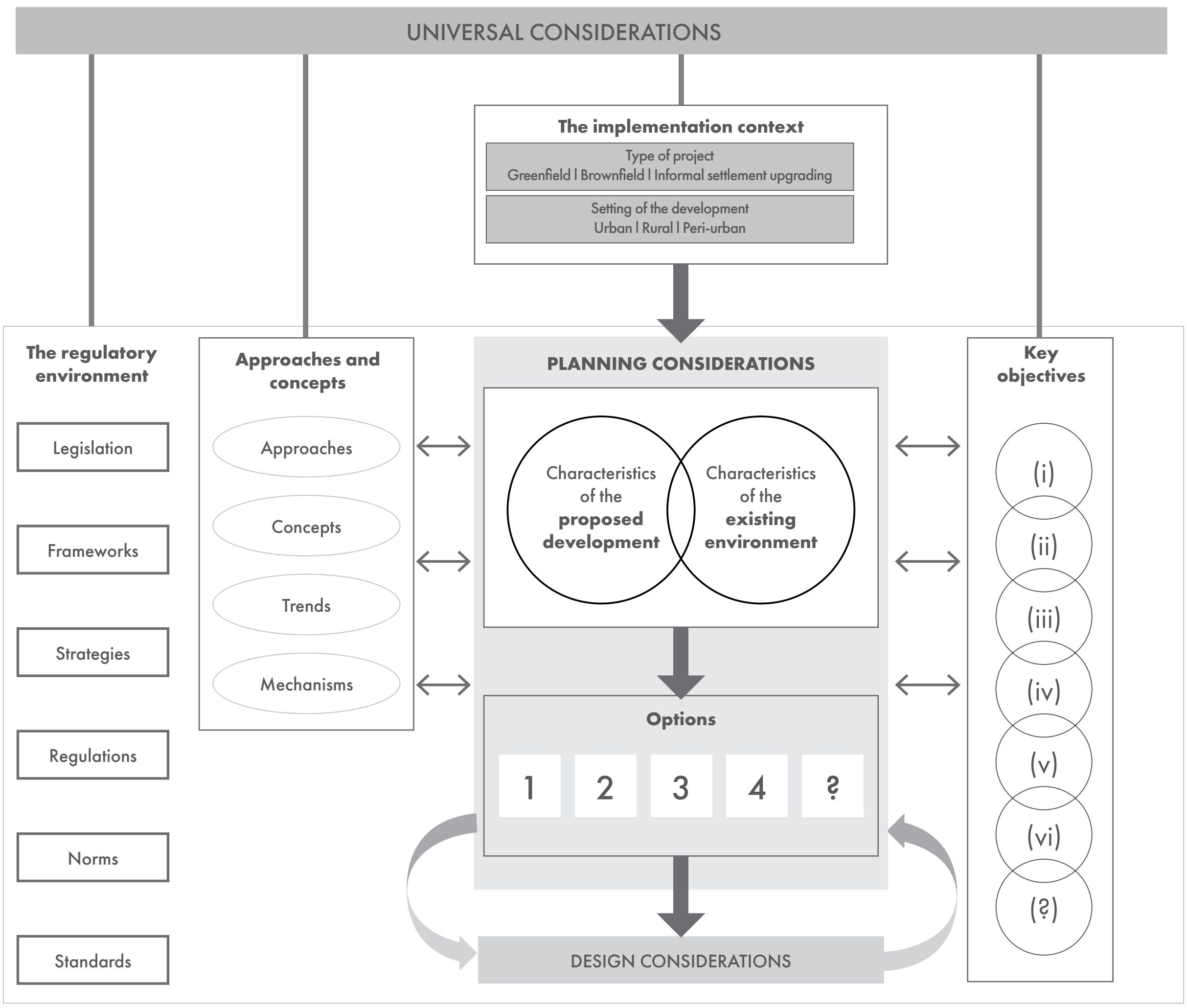


Figure M.1: A framework to assist with planning and design decisions

M.2 Universal considerations

M.2.1 The regulatory environment

A range of legislation, policies and strategies guide the planning and design of solid waste management services and related infrastructure. 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. The intention of waste management legislation, policies and strategies is to regulate waste management activities and to divert waste away from landfilling towards alternative management options while providing an appropriate service to protect human health and the environment.

All three spheres of government - national, provincial and local - play a role in waste management, whether through providing the legislative framework, implementing the prescribed norms and standards or delivering municipal waste management services.

As regulator, the National Department of Environmental Affairs (DEA) is responsible for the drafting of legislation, regulations and national norms and standards. National DEA is also the licensing authority for hazardous waste management activities, as well as for general waste management activities that will affect more than one province or traverse international boundaries. Provincial departments responsible for environmental affairs are the licensing authorities for general waste management activities and landfills within their areas of jurisdiction. District municipalities are responsible for bulk infrastructure such as regional landfills and bulk waste transfer stations for use by more than one local municipality. Metropolitan and local municipalities are responsible for waste management service delivery, i.e. street cleaning, waste collection, waste minimisation and disposal in their areas of jurisdiction.

(i) Legislation

The objective of the National Environmental Management: Waste Act, 2008 (NEM:WA) is to improve waste management in South Africa. The NEM:WA introduces the waste management hierarchy (discussed in Section M.2.3) as the basis for waste management decision-making. According to the act, each municipality must develop an Integrated Waste Management Plan (IWMP) that should be included in the municipal Integrated Development Plan (IDP). Among others, the act also describes the licensing requirements of certain waste management activities, provides guiding principles for waste management charges and makes provision for the classification and assessment of waste for disposal.

Waste classification

The NEM:WA divides waste into two classes based on the risk posed:

- **General waste:** This type of waste does not pose an immediate hazard or threat to public health or the environment. It includes domestic waste, building and demolition waste, business waste or any waste classified as non-hazardous waste.
- **Hazardous waste:** This type of waste contains organic or inorganic elements or compounds that may – owing to the inherent physical, chemical or toxicological characteristics of that waste – have a detrimental impact on public health and the environment. It includes hazardous substances, materials or objects inside business waste, residue deposits and residue stockpiles. Although hazardous waste management falls outside the mandate of municipalities, planners must take note of these waste streams as they need to be collected and transported to licensed facilities.

In addition to the NEM:WA, the following legislation also has implications for waste management:

- **National Environmental Management: Air Quality Act, 2004**
  This act specifies that waste incinerators for the thermal treatment of hazardous and general waste require an atmospheric emissions licence. The Dust Control regulations (2013) under this act are also applicable to waste facilities (landfills, composting facilities, etc.).
- **National Water Act, 1998**
  If waste is the cause of water pollution, Section 19 of the act will apply. This section places a responsibility on owners of land, a person in control of land, or a person who occupies land to prevent and remedy the effects of pollution emanating from that land on water resources.
- **National Health Act, 2003**
  This act makes provision for the Minister of Health to intervene if waste services rendered do not meet sufficient standards.

(ii) Policies and strategies

Policies and strategies under the NEM:WA include the following:

- **Municipal Solid Waste Tariff Strategy (2012)**
  This strategy outlines, among others, the financial and subsidy framework within which municipal tariff setting fits, including sources of revenue for municipal solid waste services and tariff-setting approaches. It outlines the general principles for municipal solid waste tariff setting and the different tariff options.
- **The National Waste Management Strategy (2012)**
  This strategy was developed to achieve the objectives of the NEM:WA.
- **The National Policy for the Provision of Basic Refuse Removal Services to Indigent Households (2011)**
  This policy aims to ensure the equitable provision of domestic waste removal services to indigent households. Indigent households are not expected to pay for waste removal services. The costs of providing these services therefore have to be recovered from somewhere else, typically through cross-subsidisation, and should be planned for.
- **National Organic Waste Composting Strategy (2013)**
  This strategy stipulates that composting of garden waste should be incorporated into municipal planning and recognises the job creation, SMME establishment and partnership opportunities.
- **National Policy on Thermal Treatment of General and Hazardous Waste (2009)**
  The thermal treatment of waste is an acceptable waste management option in South Africa but the feasibility under local conditions must be confirmed.

(iii) Norms, standards and regulations

Norms, standards and regulations under the NEM:WA include the following:

- **The National Domestic Waste Collection Standards (2011)**
  This document sets national standards for equitable, affordable and practical waste collection services and includes standards for separation at source; the collection of recyclable waste; receptacles; bulk containers; communal collection points; frequency of collection; drop-off centres for recyclables; collection vehicles; health and safety; communication; awareness creation and complaints; and waste collection customer service standards for kerbside collection. These standards are uniformly applicable to all municipalities.

- **Norms and Standards for Storage of Waste (2013)**
  These norms and standards aim to ensure uniform and best practices for the design and operation of new and existing waste storage facilities.
- **List of Waste Management Activities that have, or are likely to have, a detrimental effect on the environment (2013)**
  The list specifies the waste management activities that require licensing. Depending on the type and scale of an activity, a full Environmental Impact Assessment (EIA) or a scoping level assessment should be conducted as part of the licence application process for all waste management activities that may have a detrimental effect on the environment. All waste management licences are site-specific and licences for municipal solid waste activities are issued by the relevant provincial department dealing with environmental affairs.
- **Norms and Standards for Assessment of Waste for Landfill Disposal, and Norms and Standards for disposal of Waste to Landfill (2013)**
  These norms and standards stipulate that domestic waste, business waste (not containing hazardous waste or chemicals), non-infectious animal carcasses, and garden waste are pre-classified waste streams for which disposal is only allowed at Class B landfills. All new municipal landfills and new cells at existing municipal landfills must be designed and constructed in line with the specifications for Class B landfills.
- **Norms and Standards for the Extraction, Flaring or Recovery of Landfill Gas (2013)**
  The purpose of these norms and standards are to control extraction, flaring or recovery of landfill gas to prevent or minimise the potential negative impacts on the bio-physical and socio-economic environments.
- **Waste Information Regulations (2012)**
  Municipalities must keep record of all waste disposed of at their landfills and must report the data to the relevant waste information system, according to the South African Waste Information System (SAWIS) regulations.
- **Waste classification and management regulations (2013)**
  These regulations are relevant to all waste streams except those that are pre-classified. Generators of waste are responsible for the classification of waste and for the safe disposal of their waste once classified. All waste must be treated, reused, recovered or disposed of within 18 months of generation.

Each provincial department dealing with environmental affairs has its own norms and standards which may be stricter than national norms and standards. Metropolitan and local municipalities must promulgate by-laws specifying the waste management services that they provide, as well as the actions required by the residents within their area of jurisdiction.

Be aware that the establishment of new waste management facilities and the outsourcing of municipal waste management services potentially have high costs and long timeframes due to possible extensive legal processes. Some of the required processes can be run in parallel and consultation processes can be combined, but this will require integrated planning. Outsourcing of municipal services is subject to approval of a Section 78 assessment in terms of the Municipal Systems Act, 2000.

M.2.2 Key objectives

Solid waste management has strong linkages to a range of global and local issues such as climate change, public health, poverty reduction, food and resource security, and sustainable consumption and production. Waste management is therefore included, either explicitly or implicitly, in a number of the Sustainable Development Goals

(SDGs). Objectives related to solid waste management 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. Infrastructure and service provision related to solid waste management at a neighbourhood level should lower the risk to human health, minimise adverse impacts on the environment, grow the waste sector's contribution to the economy and contribute to a better life for all.

(i) Lower the risk to human health

Solid waste management should limit health hazards and prevent the spread of infectious diseases. All waste should be stored, collected, treated and disposed of in a controlled manner. Uncollected waste, for instance, attracts pests such as flies and vermin, which are potential carriers of disease. Uncollected waste can also block drains, which results in stagnant water (increasing the risk of disease transmission and water contamination). The blocking of drains due to uncollected waste can also aggravate the impact of flooding, which can cause damage to property or endanger lives.

(ii) Minimise adverse impacts on the environment

The implementation of a sound solid waste management system should minimise waste's adverse impacts on the natural environment by preventing pollution. In addition, such a system should minimise added harmful impacts on the environment that can possibly result from the methods that are used for the storage, collection, treatment and disposal of solid waste. For example, the burning of waste should be limited to prevent air pollution and landfills should be designed in such a manner that leachate is prevented (to protect underground water resources).

(iii) Grow the waste sector's contribution to the economy

The maximum possible value should be extracted from solid waste. Waste that is currently disposed of at landfills has potential to benefit communities economically. For instance, by re-introducing recycled materials to the economy, new markets can be developed (e.g. for energy or for compost). Waste collection (including recycling services) is labour intensive and could contribute to job creation in the waste sector. Waste management services should therefore be planned to involve informal recyclers (local entrepreneurs) as part of the formal waste management system.

(iv) Contribute to creating a better quality of life for all

Waste collection services should be extended to all, irrespective of income level. A better quality of life should be made possible by creating neighbourhoods that are free of pollution (water, air and soil contamination) and are attractive places to live (without litter, odours and smog).

M.2.3 Approaches and concepts

This section briefly describes the waste management hierarchy and the waste management system as concepts that support the objectives discussed in Section M.2.2.

M.2.3.1 The waste management hierarchy

Rapid urbanisation, population growth and lifestyle changes (resulting in an escalation in the use of consumer products) have led to a significant increase in the volume of waste generated in settlements. Disposing of waste at landfill sites is becoming more and more challenging, due, in part, to the shortage of suitable land in densely populated settlements and the cost of transporting waste. This could lead to an increase in illegal dumping, uncollected waste and other forms of pollution, which would pose a threat to the natural environment.

It has been recognised internationally and locally that a comprehensive, holistic approach to the management of waste is required to limit the reliance on landfill sites and reduce the negative impact of solid waste on the environment. A range of actions to reduce and deal with waste has been identified and prioritised according to their potential impact on the environment. These actions are structured in a hierarchical system, with actions that will have the least impact on the environment positioned at the upper end of the hierarchy. This system is referred to as the 'waste management hierarchy'. The intention with this hierarchy is to encourage everyone (including households, industries and government entities) to extract the maximum practical benefits from resources and products and to generate the minimum amount of waste. Various permutations of the waste management hierarchy exist, but in essence the key components remain the same. It is usually presented as an inverted pyramid as illustrated in Figure M.2.

Waste management actions are arranged in order of preference, with those that will make the most significant contribution to the effective and efficient utilisation of resources, to reducing greenhouse gas emissions and pollutants, and to conserving energy, ranked highest in the hierarchy. Therefore, according to the hierarchy, initiatives aimed at eliminating waste should be prioritised, followed by attempts to reduce waste. Waste could be eliminated or reduced by, for instance, designing and manufacturing goods in a particular way, or by reducing unnecessary consumption.

The next action in the hierarchy relates to the reuse of a product when it reaches the perceived end of its lifespan. Rather than discarding such goods, in many instances they could be refurbished, repaired or repurposed. Recycling involves the separation of certain goods from the waste stream and utilising them again as products or raw material. Certain types of waste could also be recovered to be used as fuel for energy. Disposing of waste is the least desirable method to adopt, and efforts should therefore be made to implement as many of the actions higher up in the hierarchy to reduce the volume of waste that ends up at a landfill site.

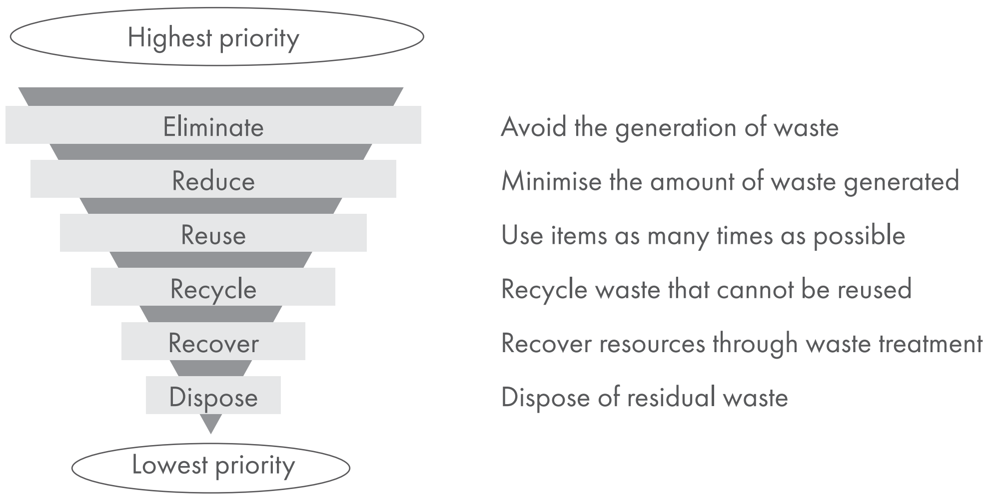


Figure M.2: The waste management hierarchy

M.2.3.2 The waste management system

The waste management system involves a range of inputs, outputs and actions. Once waste is generated, it follows a process that involves a number of stages. The stages involved would depend on the nature of the waste and the manner of disposal, as illustrated in Figure M.3. In some instances the process may be very basic, simply involving the collection of waste and its transportation to a landfill site. In other cases, especially when waste is separated at source, the process may become more complex and involve a range of other stages or actions. This may involve various recovery and treatment methods that would result in a range of outputs such as fuel, compost and recycled metal, paper, glass and plastic.

Separation of waste at source

- If only one container is used to dispose of waste, the waste is not sorted and therefore may include a mix of organic waste (garden and food waste), recyclables (paper, glass, metal, plastic) and non-recyclable waste.
- If waste is disposed of in two containers, one container is usually used for mixed recyclables and the other for a combination of organic and mixed non-recyclable (residual) waste.
- Three or more containers would allow for further separation of the different types of recyclables and/or the separation of organic and residual waste into different containers.

The waste management system illustrated in Figure M.3 is a generic system that may have to be modified to suit specific conditions and local contexts. The way in which waste is disposed of in a particular area may change over time, and therefore the system should be adaptable. For example, initiatives may be implemented to minimise waste generation and encourage reuse, which will reduce the volume of waste to be collected, transported and treated. Similarly, if it becomes mandatory for households and other waste generators in a particular area to separate waste at source, the way in which waste is collected, stored and treated may change substantially (e.g. a clean Materials Recovery Facility (MRF) may be needed instead of a dirty MRF).

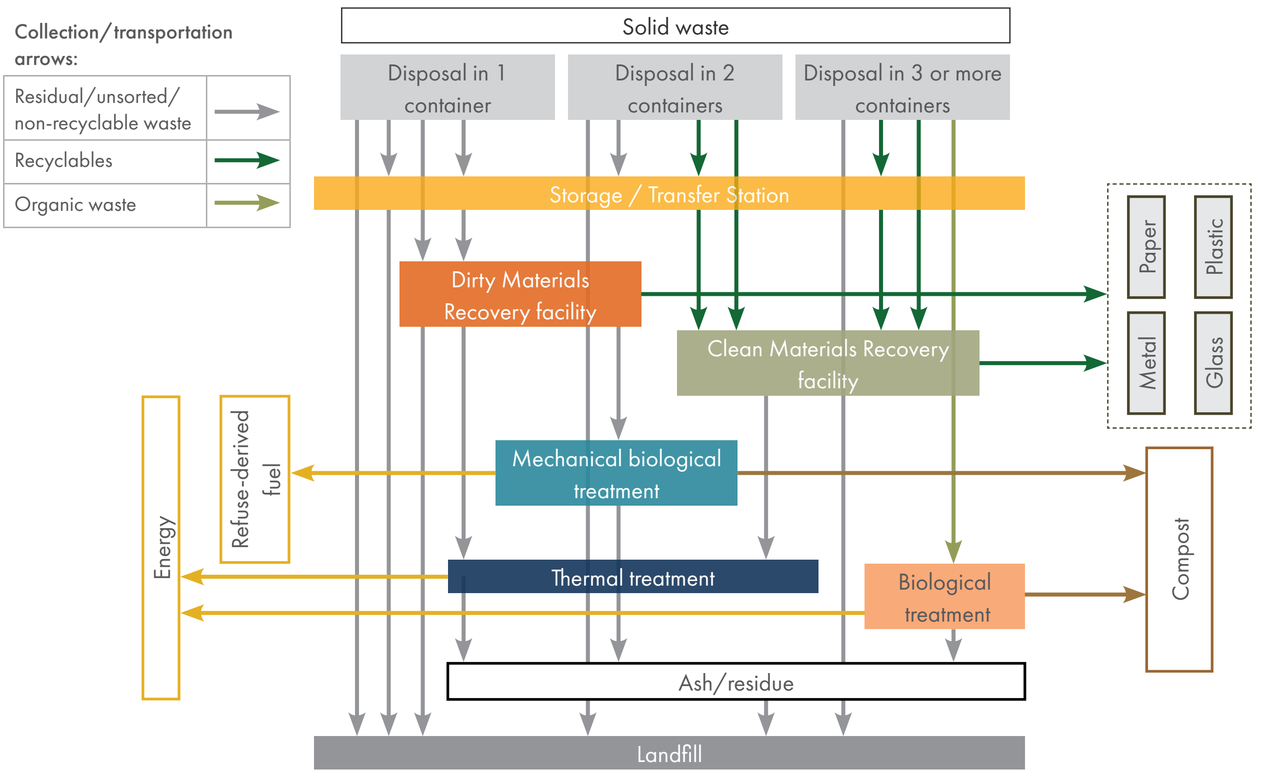


Figure M.3: The waste management system

M.2.4 The implementation context

This section highlights the contextual factors that should be considered when making decisions regarding solid waste management, specifically related to the type of development and its setting.

M.2.4.1 The type of development

(i) Greenfield development

Deciding on a solid waste collection system for a greenfield development would normally be influenced by the anticipated needs of the residents and the cost implications of a proposed system. Other factors that would influence the choice and design of a solid waste collection system include the topography and geotechnical conditions on the greenfield site. Illegal dumping sites may exist on the proposed greenfield site. These will have to be rehabilitated to discourage continued dumping or they may be converted to legal dumping sites if the final layout of the neighbourhood allows. If there is an existing waste collection service in adjacent neighbourhoods, the additional pick-up points and additional volumes of waste of the new development might affect the capacity of the existing waste management facilities and the distances to be covered by vehicles collecting the waste.

(ii) Brownfield development

Since brownfield sites are part of the fabric of an existing city or town, a solid waste removal system may exist, which may be able to accommodate the additional volumes of waste. A change in land use brought about by the brownfield development, e.g. the conversion of office blocks to blocks of flats, or using a parking lot to construct an office block, will affect the solid waste management service that is needed. Brownfield developments are often associated with higher population densities, which will increase waste volumes per area.

The existing topography and access conditions of the site (e.g. widths of streets, steep gradients and cul-de-sacs) may affect the collection of solid waste, while the availability of space and the geotechnical conditions of the site may determine whether additional waste management facilities can be provided. Illegal dumping spots may exist and would need to be rehabilitated to deter future dumping at these spots.

(iii) Informal settlement upgrading

Informal settlement upgrading projects are usually complex undertakings that require extensive community participation, specifically to agree on the solid waste management system to be provided. The layout of the upgraded settlement may have an effect on waste collection. For instance, narrow street widths can make it difficult for collection vehicles to pick up waste from individual houses. Alternative waste collection options should then be considered, e.g. central collection points that can be reached by waste collection vehicles.

Informal settlements could be located in established parts of towns or cities where they can be linked to existing waste collection systems. Often informal settlements are located on the peripheries of cities and towns where no solid waste collection systems are in operation. This would require careful planning to link the upgraded neighbourhood to the existing waste collection system and would possibly involve the establishment of new waste management facilities as part of the upgrading initiative. Informal settlements often have central points where waste is dumped. When planning the waste management service, these illegal dumping sites should be considered as sites for formal waste management facilities.

M.2.4.2 The setting of the development

(i) Urban

Urban settings can take on different forms and this will influence the type of waste collection system to be provided. Within urban areas, large volumes of waste are usually generated in relatively small areas due to population and housing densities. This can result in sufficient thresholds to improve efficiencies in the waste management system. Larger distances to landfill sites may require more transfer stations and increase the need for long-haul vehicles.

(ii) Peri-urban

The nature of developments within peri-urban areas can vary considerably, and so will the solid waste systems to be provided. As with the other development settings, it is important that the service provided must be responsive to the needs of the residents. When deciding on service levels in peri-urban areas, the service levels in the neighbouring urban areas should be noted as they may have an (sometimes unpredictable) impact on the waste management services in the entire area. For example, areas serviced by wheelie bins are often victims of bin theft if neighbouring areas are not issued with similar bins. Constant replacement of stolen bins can be more costly than simply upgrading the service in the peri-urban area.

(iii) Rural

Development sites in rural areas will vary in nature depending on the location, for instance whether the site is situated in a rural town or in a dispersed settlement. The waste collection system appropriate to the setting will also vary and be dictated by a range of factors. Due to lower population densities, the provision of solid waste collection systems in rural areas may sometimes require approaches that differ from those taken in cities or towns. For example, the distance to the nearest large landfill site or to recycling markets may affect the choice of waste management system. If on-site solid waste disposal (usually the burning of waste) is the only option, it should be done under supervision of a relevant municipal official. Assistance with the supervision of on-site disposal can be arranged with district municipalities or provincial departments responsible for environmental affairs.

M.3 Planning considerations

This section deals with the planning of solid waste services and infrastructure. In this context, the term 'planning' means making informed decisions regarding the storage, collection, transport, treatment and disposal of solid waste, and then choosing the most appropriate options based on a thorough understanding of the context within which the planned development will be implemented.

The decisions regarding solid waste management 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.

This section outlines a range of questions should be asked and factors that have to be considered before deciding on the most appropriate solid waste management infrastructure and service.

M.3.1 Characteristics of the proposed development

Decisions regarding solid waste management infrastructure and services 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.

M.3.1.1 The nature of the proposed development

The type of development will determine the potential users of a solid waste management service and, in turn, the types of waste streams as well as the volumes of each waste stream that can be expected. This information is needed in order to plan an appropriate solid waste management service and to calculate whether existing solid waste management facilities will have sufficient capacity to handle the increase in waste volumes. The following questions can be asked to gain clarity:

- What is the dominant land use of the proposed development?
- What types of housing will be provided in the proposed development? What population densities are anticipated in the proposed development?
- What other land uses will form part of the proposed development? The number and size of different business properties, public open spaces, schools, clinics and public transport facilities will affect waste generation.

M.3.1.2 The residents of the area to be developed

Decisions regarding a solid waste management system should be guided by information about the residents of a neighbourhood. Usually, the identities of the actual occupants of the houses to be provided are not known when a development is planned and designed. It may be possible to make assumptions regarding the expected profile of the future residents by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to establish the following:

- The total number of residents to be accommodated. Actual numbers may be higher than anticipated because the provision of houses and services may attract more people than originally planned.
- The number of households and the range of household sizes. The household information will likely be aligned with the anticipated residential building type, for instance single detached housing, semi-detached housing, attached housing or flats. This will provide an indication of the number of solid waste collection points that have to be serviced as well as the number of households to be serviced at a point.
- The range of residents with special needs that would have to be accommodated, for example people living with disabilities. Waste management facilities should (where relevant and possible) be accessible to all residents and users. Waste storage receptacles should be fit for use by all.
- Income and employment levels and spending patterns. This would, for instance, indicate the anticipated ability of the intended users to pay for waste collection services. It could also give an indication of the volume of waste that will be generated in the area.

M.3.2 Characteristics of the existing environment

Decisions regarding solid waste management 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.

M.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the project site could influence the solid waste infrastructure and service to be provided.

(i) Topography and geotechnical characteristics

The topography and geotechnical conditions of the project site might affect the type of solid waste management service that is selected. The following has to be considered:

- Do the access roads in the neighbourhood have steep slopes? Heavy solid waste collection vehicles have difficulty climbing steep slopes. The collection of solid waste may be more expensive in neighbourhoods with steep slopes due to the increased time it takes for trucks to move along steep roadways.
- The type of soil and the presence of water sources in the area may have an impact on the type of waste management facilities that can be provided. For instance, a landfill facility may not be appropriate in an area that has a relatively high water table.

(ii) Adjacent land uses and edge conditions

Adjoining properties have an impact on each other. Therefore, it is important to be aware of the land uses adjacent to the development site as well as of the edge conditions that affect the site. Some of the questions that need to be asked include the following:

- What are the existing land uses in the area or in surrounding neighbourhoods? Information on the type and amount of waste generated by the different land uses in the vicinity will inform decision-making on solid waste management services and infrastructure.
- Are there illegal dumping sites in the area? Where are these located? What are the possible reasons for the illegal dumping and how can it be avoided in future? Could any of these sites be developed into formal waste management facilities?

M.3.2.2 Available infrastructure and services

New developments create additional demand for services and therefore have a potential impact on existing services and infrastructure. The following information on existing solid waste management infrastructure and services in the area or in surrounding neighbourhoods has to be considered:

- What waste management facilities are currently operational in the area? (Refer to Section M.4.3)
- What is the capacity of existing waste management facilities and will these facilities be able to handle additional waste loads? What impact will the additional waste loads have on the lifespan of the existing waste management facilities?
- What vehicles and equipment are available for waste collection, storage and disposal?
- Does the road infrastructure of the area – the layout, length and width of streets – support easy access and manoeuvrability for waste collection vehicles to render an efficient and cost-effective waste collection service? Can the existing roads carry the waste loads between different waste management facilities and between waste management facilities and collection points?
- Are there existing initiatives for waste minimisation, reuse and recycling in the area? If yes, do households and businesses separate waste at source? Who is responsible for recovering recyclables? Are there existing markets for additional recyclables or will new markets have to be created?

The first port of call to find information on existing solid waste management is the Integrated Waste Management Plan (IWMP) for the municipality. The IWMP provides input to the Integrated Development Plan (IDP).

The IWMP includes a situation analysis with a description of the population in the area, a description of the services that are provided and the number of persons in the area who are not (yet) receiving waste collection services. The situation analysis also refers to existing institutional, financial, legal and physical conditions. The planning of waste management services in the municipality for the next five years is also included as part of the IWMP.

More information is available in the *Guideline for the development of Integrated Waste Management Plans.*[1]

M.3.3 Solid waste management options

M.3.3.1 Factors to consider when choosing waste collection options

Waste is generated at, among others, residences, businesses, schools and clinics. The type of waste from each of these points will differ, and the waste management service requirements will differ accordingly. A thorough understanding of the types and volumes of waste that will be generated in any new development will assist the municipality in minimising negative public health and environmental impacts that might result from inadequate solid waste management. Knowing the expected volumes and types of waste will assist in selecting an appropriate waste collection service for a neighbourhood (Section M.3.3.2) and subsequently the receptacles and storage at the point of generation (Section M.4.1), the number and size of collection vehicles (Section M.4.2), as well as the size, capacity and expected turnaround times of waste management facilities (Section M.4.3).

Waste flow projections are used to predict the volumes and types of waste that will be generated. This section provides guidance on how to do waste flow projections for an area by calculating future waste generation, estimating the composition of municipal solid waste and assessing the mass of municipal solid waste.

(i) Current and future solid waste generation

A first step towards doing waste flow projections is to determine the current solid waste generation of the neighbourhood. Calculate the waste generation per household per year or per population per year by using existing per capita information. Waste generated per capita may be based on available local figures or on existing estimates for domestic waste generation. Estimates can range from 0.41 kg/capita/day for low-income households to 1.29 kg/capita/day for high-income households.[2] The population of the area refers to the total number of people living in the area.

Equation M.1: Waste generation per household (tonnes/annum)

$$\text{waste generated per capita (kg)} \times \text{number of people per household} \times \frac{365}{1000}$$

Equation M.2: Waste generation for an area (tonnes/annum)

$$\text{waste generated per capita (kg)} \times \text{population of the area} \times \frac{365}{1000}$$

Using the current waste generation as a baseline, projections can be done for new developments. An expected waste generation growth rate can be based on anticipated population growth and/or anticipated economic growth. Domestic waste generation estimates are calculated using population growth rates, while industrial waste generation estimates are calculated using economic growth rates. This formula does not apply to garden waste estimates.

Equation M.3: Future waste generation (tonnes/annum)

$$\text{waste generation } (t/\text{a}) \times \text{population growth estimate (\% per annum)}$$

(ii) Composition of solid waste

Different waste streams require different types of storage, collection and treatment. Although the composition of municipal waste varies depending on local conditions, estimates can be made of waste generation per waste stream.

The *National Waste Information Baseline Report* [3] suggests that about 44% of all municipal solid waste originates from households. The following general assumptions can be useful when estimating the composition of municipal solid waste (the percentages are per weight):

- 15% organic (garden and food waste)
- 20% construction and demolition waste (builders' rubble)
- 25% mainline recyclables (paper, plastics, glass, tins and tyres)
- 40% non-recyclable waste

(iii) Solid waste mass

Information on the mass of solid waste is critical when determining the capacity requirements for waste transport and for waste disposal facilities. Waste data may be available in volume (m^3) or weight (kg). Use waste densities to convert waste volumes to estimated weights and vice versa. Waste densities differ depending on the type of waste and whether or not the waste has been compacted. Refer to Table M.1 for densities of different types of waste to estimate the waste mass by using the equation below.

Equation M.4: Waste mass (kg)

waste volume (m^3) x density (kg/m^3)

Table M.1: Typical densities by solid waste type [4]

Waste category	Waste type	Density (kg/m^3)
Domestic	Domestic waste compacted in rear-end loader	500
	Domestic waste (uncompacted)	200
	Mixed domestic /garden waste (more domestic than garden)	200
	Mixed domestic /building rubble (more domestic than building)	250
Commercial/Industrial	Packaging (paper and plastics)	200
	Timber/metal	150
	Tyres	150
Inert waste (construction waste)	Building rubble/concrete/sand/fibreglass/brick/ceramics	750
	Building rubble/industrial mix (more building than packaging)	350
	Building/garden mix (more building than garden)	250
Garden waste	Loose grass/small branches	200
	Large logs	400
	Garden /building mix (more garden than building)	250
Perishable waste	Food waste/animal fodder	840

M.3.3.2 Collection options for municipal solid waste

Municipalities should plan a waste management service that will comply with legislation and with service expectations, while ensuring that the key objectives are met (refer to **Section M.2.2**). A basic refuse removal service can be defined as the most appropriate level of waste removal service based on site-specific circumstances.[5] Although an equitable waste collection service must be provided to all households, the *National Domestic Waste Collection Standards*[6] (set in line with the NEM:WA) recognise that service levels may differ between areas depending on contextual considerations.

Cost recovery for solid waste management

Solid waste management services are financed through municipal rates and taxes. However, municipalities often struggle to pay for the necessary infrastructure and the other costs associated with solid waste management of new developments. New development projects should ideally not place a financial burden on existing rate payers. Costs for new site-specific infrastructure can potentially be recovered through a contribution or levy that is paid by the developer to the municipality. Therefore the waste management service provision in new development projects (greenfield, brownfield and informal settlement upgrading) should be determined and costed (in cooperation with the municipal department responsible for solid waste management) before approval of the project by a municipality.

Similar arrangements are often made to recover costs of engineering service infrastructure for water supply, sanitation and electricity. Existing municipal policies on development contributions or levies could be expanded to include solid waste management.

The choice of service level for solid waste collection will be influenced by the size, density and waste-generating potential of a neighbourhood, as well as issues such as road conditions and the distance between the neighbourhood and waste management facilities. Deciding on the most appropriate waste collection system is an iterative process that requires information on the following:

- Waste flow projections to determine the amount of waste that will be generated for each waste stream and the frequency at which this waste will likely be generated (refer to Section M.3.3.1).
- The spatial distribution of the waste generation points. This can be done by considering the spread of land uses, housing types and densities.
- The possibility of recycling and recovering of solid waste (refer to Figure M.3 for an illustration of the waste management system). Will enough waste be generated to sustain the implementation of alternative treatments?
- The options for labour-intensive or job-creating collection services. This consideration is relevant to all neighbourhoods, but in particular to neighbourhoods where the provision of conventional services might be challenging (e.g. where long distances have to be covered or where municipal waste collection vehicles are not able to access an area).

Four conventional collection systems are presented below. Different systems are usually implemented in combination.

(i) Door-to-door or kerbside collection

In this system, domestic and non-hazardous business waste are placed (in receptacles) on the sidewalk to be collected by the municipality, service provider or local entrepreneur. The collection is usually done with purpose-built vehicles.

Kerbside collection increasingly also has to cater for recyclables that are separated at source. Different receptacles are required for source-separated waste (refer to Section M.4.1). Aspects to consider for the kerbside collection of different waste streams include the following:

- One vehicle can be used for collecting different waste streams by using a split compartment vehicle or a truck-and-trailer combination.

- Different vehicles can be used for different waste streams. Implementing separate vehicle collections will reduce the load collected by each vehicle per collection point but could affect traffic movement in the area on collection days if the streets are not wide enough.
- The municipality can partner with local entrepreneurs to collect some of the waste.

(ii) Central collection points

In this system, households or local entrepreneurs are required to place the waste or recyclables into strategically positioned bulk containers for collection and removal by large motorised vehicles. These containers must be placed at a convenient location not far from households and accessible to waste collection vehicles for easy removal.

A central collection point is often used in areas where poor access hampers kerbside collection, for example in informal settlements or high-density areas where the layout and/or road conditions restrict the access of waste collection vehicles. This system is also an option for household waste collection in rural areas where it may not be financially feasible for the municipality to do door-to-door collection.

Central collection points, combined with drop-off or buy-back centres (see **Section M.4.3**), can be considered for source-separated recyclables in areas without kerbside collection for recyclables. Central collection point systems may include exchange and underground containers (refer to the sections below). Containers used at central collection points should be fit for use to a range of users. For example, children or people with disabilities should be able to deposit waste into the container without any difficulty.

(iii) Exchange-container collection systems

Exchange-container collection systems entail replacing the full container with an empty one on the collection day. Static compactors and skips are examples of exchange containers. This collection system is typically used at the following locations:

- Markets or other places where high volumes of waste must be removed on a daily basis
- Industries and places where (usually non-biodegradable) waste is collected less frequently than household waste
- Building sites where building rubble must be collected and removed
- Waste transfer stations, where solid waste is deposited into large containers for storage until it is collected for long-haul transport to landfill sites
- Central solid waste collection points such as recycling centres

(iv) Underground container systems

This system makes use of specially designed waste containers that are positioned underground or partially underground. The underground system can either be a stand-alone collection point or it can incorporate an automated vacuum collection system (also referred to as a stationary pneumatic collection system). Underground containers can hold large quantities of waste and have the advantage that the waste is protected from the elements (specifically rain and wind). The chances of the waste polluting the immediate surroundings are therefore limited.

Underground containers are used in public open spaces, in areas with high pedestrian densities, and in urban areas where conventional door-to-door collections are challenging due to topography or limited space for waste containers. Underground containers come in a variety of designs and forms, and usually require specialised vehicles for lifting.

Photo credit: Pikitup

Figure M.4: Specialised vehicles are used to empty underground containers

Solid waste collection frequency

The frequency of solid waste collection depends on the type of waste. For instance, restaurant waste is collected daily while household waste is collected weekly. The collection could also be event-specific, for example after an event at a sports stadium. The following frequencies are recommended for waste collection:

- Remove non-recyclable (residual) waste once a week to avoid waste-related nuisances and possible public health impacts.
- Remove recyclable waste at least once every two weeks. This should be coordinated with recyclers or local entrepreneurs to minimise cost and to ensure that local waste management facilities have enough capacity to accept and process the recyclables.
- Empty containers at communal collection points when they are full, to prevent the spilling of waste.
- Collect putrescible waste generated by hotels, restaurants, food shops, hospital kitchens and canteens daily to prevent the waste from decomposing and presenting a possible health risk.

M.4 Design considerations

Once an appropriate waste collection system has been selected, the solid waste management service and accompanying infrastructure can be designed. Decisions should be made regarding storage, transport, treatment and disposal of solid waste.

The location of proposed waste management facilities has to be considered when the layout of a new or upgrading project is done (refer to **Section F** for guidelines on neighbourhood layout and structure). The decisions regarding solid waste management services must take place in tandem with the design of engineering services (including water provision, sanitation and stormwater management) to ensure that the service will be ready for implementation at the time of occupation of the new development. Apart from the obvious convenience to the user, the availability of a solid waste management service will assist in preventing illegal dumping. Clearing of illegal dumping and littering is usually more expensive than providing effective and reliable waste collection services from the start.

M.4.1 Receptacles and storage at point of generation

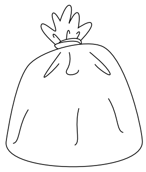
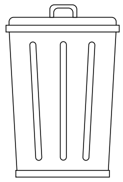
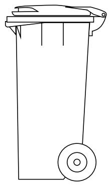
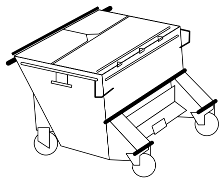
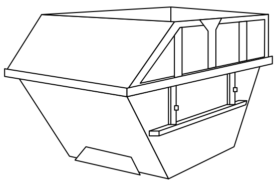
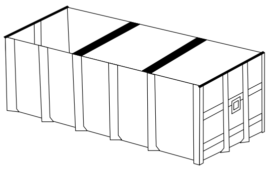
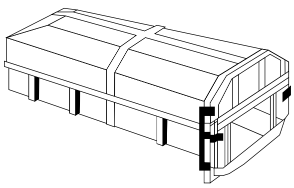
This section describes the storage of waste at the point of generation, which can include different types of housing (e.g. single detached or blocks of flats), shopping centres, clinics, schools, etc. Waste is also stored at collection points for recyclable materials and at transfer stations where waste is accumulated before being transported over longer distances (see **Section M.4.3**).

M.4.1.1 Solid waste receptacles

If a kerbside collection service is selected, bins or bags are placed on the sidewalk for collection. The empty bins or bags are returned to the sidewalk. Municipalities are not obliged to provide individual domestic bins to residents. However, the provision of a bin per household has proved to lower the risk of illegal dumping.[7] In South Africa, formal neighbourhoods are typically serviced by means of 240 *l* wheeled bins, although other sizes are also available on the market. Bulk containers ranging in size from 5 m^3 to 30 m^3 and large static compactors are mostly used for business waste. Static compactors are recommended for all office developments larger than 5 000 m^2.

Table M.2 shows examples of receptacles that are compatible with a kerbside collection service. Containers will differ depending on the waste collection system that is suitable for a specific area and whether waste is separated at source.

Table M.2: Containers for on-site storage

Description	Common usage		Collection methods	
85 to 105 *l* plastic bin liners	• Domestic/household • Small business and industry • Public amenities		By hand on site, or on sidewalk Liners deposited directly into collection vehicle	Storage containers emptied on site
85 *l* rubber/ galvanised steel bins	• Domestic/household • Small business and industry • Public amenities		By hand on site, or on sidewalk Liners deposited directly into collection vehicle	
120, 140 or 240 *l* mobile refuse bins (wheelie bins)	• Domestic/household • Small business and industry • Public amenities		Rear-end loading compactors with special lifting equipment	
1.0 and 1.2 m^3 mobile refuse containers	• Small business and industry		Rear-end loading or front-end loading compactors with special lifting equipment	
4.5, 5.5, 6, 9 and 11 m^3 bulk containers	• Large business and industry, garden refuse, building rubble, public amenities • Bulk waste and communal collection systems		Skip loaders Rear-end loading compactors with special lifting equipment	Exchange storage containers
15 to 30 m^3 open bulk containers	• Large business and industry, garden refuse, building rubble • Bulk waste and communal collection systems		Roll-on/roll-off vehicles	
11, 15 and 35 m^3 closed containers	• Large shopping centres, transfer stations and selected industries		Roll-on/roll-off vehicles	

M.4.1.2 On-site storage of solid waste

An on-site waste storage facility is used for storing waste from the time of generation until it is collected. Bulk containers, compaction units and large numbers of bins that are ready to be collected require on-site storage facilities that are accessible to waste collection vehicles. The preferred position of the waste storage area is close to the main entrance or service entrance of the property. Consider the following:

- A housing complex with fewer than 10 units usually does not require a central storage space, but this would depend on the overall layout of the units (e.g. whether there is space for a wheelie bin at each individual unit, or whether waste at each house is collected in bags to be transferred to wheelie bins in a storage area).
- Housing complexes with 10 to 20 units are best serviced by a single centralised waste storage area where there is enough space for the collection vehicle to load the waste inside the property and minimise the impact of waste collection on traffic.
- Larger complexes of more than 20 units require a site-specific plan to ensure effective and efficient waste collection. The plan can include door-to-door collection if road access is sufficient (refer to **Section M.4.2** on the requirements of different collection vehicle types) or collection from central points where bulk containers or static compactor units are provided in centralised waste storage areas. There are various types of compactors available to suit different types and sizes of developments.

In instances where central collection points are the most practical service option (including attached housing, flats/ apartments and office blocks), additional storage space is often required. For more information on the need for additional storage space, refer to the *National Domestic Waste Collection Standards*.[8]

The dimensions of the two common bin types that are used in South Africa are provided in Figure M.5. Sometimes static compactors are also provided on site. The space required will vary depending on the container capacity. The site should be designed to accommodate the compactor, containers and a roll-on/roll-off vehicle.

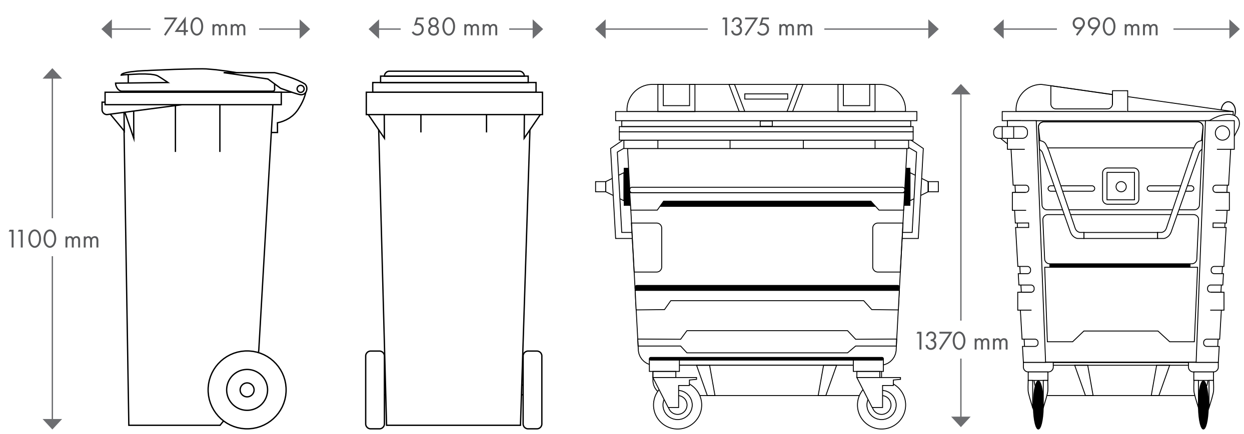


Figure M.5: Waste receptacles commonly used in South Africa include the 240 *l* bin (L) and the 1 100 *l* bin (R)

Public cleaning services

It is the responsibility of municipalities to sweep streets, maintain and clean road verges, empty bins and clean public open spaces. The collection of illegally dumped waste and the prevention of illegal dumping also form part of municipal solid waste management. Measures to prevent litter include the following:

- Avoid empty spaces that are prone to become illegal dumping spots. Beautify areas such as street corners and add adequate waste and recycling bins that are emptied regularly.
- Provide enough strategically positioned and clearly marked litter bins (for residual waste and recyclables) in public open spaces and along pedestrian walkways. Match the number and size of bins in public open spaces with the following:
  - The foot traffic density
  - The frequency at which bins will be emptied
  - The foot traffic mobility (free-flowing or queueing?)
  - The activity in the area (e.g. local taxi ranks typically generate more waste than suburban parks)

The management of solid waste and specifically the avoidance of litter are critical to the efficient functioning of stormwater management systems. Litter can block sewers and stormwater canals which may lead to pollution. It may also aggravate the impact of flooding, causing damage to property and endangering lives. Refer to Section L for guidance on the planning and design of neighbourhood stormwater management systems.

M.4.2 Transport of solid waste

Solid waste collection and transport in South Africa is mostly done using motorised vehicles. Consider the waste collection vehicle to be used and the accessibility of the neighbourhood when designing for the transport of solid waste.

M.4.2.1 Waste collection vehicles

The types of vehicles used by the waste management industry in South Africa range from basic hand carts to technically sophisticated and motorised front- and rear-loading compaction vehicles. When deciding on a type of vehicle, the following should be considered:

- Select a vehicle that is appropriate for the type and volume of waste. For example, a caged truck is suitable for waste that does not need compaction.
- Select a vehicle type that is appropriate for the specific road conditions in the area. For instance, a tractor and trailer may be appropriate for a rural gravel road where trucks may have difficulty to drive.
- Select a vehicle size that is appropriate to the street layout in the area. For example, the turning circle of a large compaction vehicle is not compatible with small cul-de-sac streets.
- Ensure compatibility between supplied waste containers/receptacles and collection vehicles.

Determine the number of vehicles required to provide an effective waste collection system by considering the capacity of the collection vehicle, the number of households to be serviced per day, the average waste generation per household and the distance to the disposal facility (see Section M.3.3.1).

The dimensions (e.g. ground clearance, length, height, width, weight and required turning circle) of waste collection vehicles have to be taken into consideration in the planning and design of neighbourhood street layout and road pavements to ensure that these vehicles can access neighbourhoods without difficulty (refer to Section M.4.2.2). The waste collection and transport vehicles that are most widely used in South Africa are presented below. Information about the features of the various vehicles is provided and issues to consider in the design of neighbourhood waste collection systems are highlighted. A short distance is regarded as being below 5 km, while a medium distance would be between 5 and 20 km and longer distances exceed 20 km.

(i) Push carts or caged waste tricycles

The dimensions of push carts and waste tricycles vary, but these vehicles often have capacity for between 1 m^3 and 3 m^3 of waste. Push carts are mostly used by local entrepreneurs or recyclers to collect waste from individual households. These types of vehicles are particularly suitable for the collection of recyclable and/or residual waste in small to large informal communities without formal waste collection and in areas with central collection points (see Section M.4.3.4). Push carts are increasingly used in middle- to high-income neighbourhoods as well, where they are used for collecting recyclables.

Push carts and waste tricycles can only cover short distances and would need a waste management facility (see Section M.4.3) such as a buy-back centre or drop-off facility within its operational range. A central collection point can also take the form of a large collection truck that serves an area once a week (on the day that household waste is placed on the sidewalk for collection).

(ii) Animal-drawn carts

Animal-drawn carts are sometimes used to collect waste in rural, peri-urban or low-density areas where low volumes of residual and/or recyclable waste have to be transported over longer distances. The capacity of an animal-drawn cart varies according to the design of the vehicle. These carts can cover short to medium distances and would need a waste management facility (see Section M.4.3) such as a buy-back centre or drop-off facility within its operational range.

Photo credit (L): Annemarie Loots

Figure M.6: Waste can be collected by local entrepreneurs using a push cart (L) or by using a tractor and trailer (R)

(iii) Tractors and trailers

Tractors and trailers are often used to collect and transport waste in smaller towns and in rural areas. A tractor and trailer combination can operate where road conditions are not suitable for trucks. The capacity of the trailer varies according to the design. These vehicles can cover medium-range distances (between 5 and 20 km) and would need a waste management facility (see Section M.4.3) such as a drop-off facility or a transfer station within operational range.

(iv) Caged trucks

Caged trucks are often used for waste that does not need compaction and has to be transported over medium-range distances. The capacity of the vehicle depends on the design of the cage and the size of the truck.

Figure M.7: Examples of a caged truck (L) and a tip truck (R) that are used for waste collection

(v) Tip trucks

Tip trucks are used to transport heavy waste loads over medium to long distances. These vehicles have a back part that can be raised at one end so that the waste falls out. With large tip trucks, the weight of the moving waste can assist with compaction.

(vi) Front-end loaders

Front-end loaders are used to collect waste and transport heavy waste loads over medium to long distances. These trucks are equipped with a bin lifter at the front of the vehicle. The driver operates the bin lifter from within the cabin to lift waste containers over the truck. Once it gets to the top, the container is flipped upside down and the waste is emptied into the vehicle. The waste is compacted and when full, the waste is discharged from the back of the vehicle. Front-end loaders have a large carrying capacity and are specifically suitable for the collection of bulk containers.

Figure M.8: Examples of a front-end loader (L) and a rear-end loader (R) that are used for waste collection

(vii) Rear-end loaders

Rear-end loaders are used to collect waste and transport heavy waste loads over medium to long distances. These trucks have an opening at the rear for the disposal of waste. Waste bags are thrown in by waste collectors or bins are emptied into the truck by using a bin-lifting mechanism. The waste is compacted and when full, it is discharged from the back of the vehicle. Rear-end loaders usually have a large carrying capacity due to waste compaction.

(viii) Skip loaders

A skip loader is a specially designed truck for loading and transporting skips (large open-topped waste containers). Skip loaders collect waste containers from industries, large businesses and building sites and transport the waste over medium to long distances. Skips are often used at central collection points in communities with or without kerbside collection.

Figure M.9: Examples of a skip loader (L) and a roll-on/ roll-off vehicle (R) that are used for waste collection

(ix) Roll-on/roll-off vehicles

Roll-on/roll-off vehicles are specially designed trucks that transport rectangular waste containers between collection and disposal points. The truck raises a hydraulically operated bed to roll the container onto the ground. A cable and winch system or a hook-lift system is used to lower the container onto the ground and to pull the filled container onto the truck. Roll-on/roll-off vehicles collect waste in bulk containers from industries, large businesses and building sites and transport the waste over medium to long distances. Some of these containers are enclosed (not open on top) and can compact the waste. Compaction increases the capacity of these containers.

(x) Rail

Waste removal by rail is used to transport heavy waste loads over long distances, especially to regional landfill sites. It is also suitable for hauling recyclables to recyclers over long distances. It is a cost-effective transport option with available (often underutilised) infrastructure, especially if operated during off-peak periods. Transport of waste still has to take place to and from the railway depot, using one of the vehicles discussed earlier.

M.4.2.2 Waste collection vehicle access

Waste collection vehicles should be able to access neighbourhoods without difficulty. When designing street layout and road pavements, the following should be considered to ensure that road infrastructure (streets, bridges, entrances, structural foundations) can accommodate waste collection vehicles:

- **Loading**: Road pavements should be designed to have the structural capability to carry a waste collection vehicle that is filled to capacity. Refer to Section I for guidance on the load-bearing capabilities of roads.
- **Space for manoeuvring**: Turning areas (often in cul-de-sacs) should be sufficient to allow the waste collection vehicle to turn with no more than three manoeuvers (refer to Section F.4 for guidance on street width). Motorised collection vehicles should move in a forward direction most of the time. In the exceptional circumstance where such a vehicle is required to reverse, the distance should be very short and should not be up or down a slope or ramp.
- **Clearance**: Bridges and entrances/gates (at residential, retail and industrial complexes) should be wide enough and high enough to allow easy access for waste collection vehicles. Waste collection vehicle dimensions give an indication of access requirements (e.g. gate width or overhead clearance) when designing facilities.

The planning of waste collection as part of a brownfield project or an informal settlement upgrade project will have to adapt to the existing neighbourhood street layout. Alternative waste collection methods (e.g. collection by local entrepreneurs) may have to be introduced in areas that do not have sufficient access for large waste collection vehicles.

M.4.3 Solid waste management facilities

Waste management facilities deal with the storage, sorting, treatment and final disposal of waste and may include transfer stations, buy-back centres, drop-off centres, materials recovery facilities, treatment facilities and landfill/disposal sites. Different waste management facilities are required as part of a waste management system (see Figure M.3) that is aligned with the waste management hierarchy (see Figure M.2). New solid waste management facilities that are provided in a neighbourhood must be appropriate to local conditions. The following should be considered:

- Match the proposed waste management facilities with the type of waste generated and the waste collection method that is used in the area.

- Find agreement on the exact location of a proposed waste management facility in collaboration with the local community. Facilities should be placed such that they do not interfere with pedestrian movement, create an eyesore, or become a public nuisance because of dust, odour or poor maintenance. Position larger or more sophisticated waste facilities at a location that will allow easy access to major routes.
- Consider converting existing illegal dumping spots to legal waste management facilities if the layout of the neighbourhood allows. It is often difficult to stop people from using a dumping site that was established informally. Refer to *Municipal waste management – good practices*[9] for ideas on how to turn illegal dumping spots into areas that communities take ownership of.
- Comply with the requirements of both the local and provincial authorities, particularly in respect of road pavement design and traffic flow at intersections and access roads. The increased number and higher frequency of heavy waste collection vehicles may have an impact on the character of a neighbourhood.
- Design the layout of waste management facilities to ensure the easy, fast and effortless flow of day-to-day operations and the convenience of those frequenting the facilities (e.g. residents making use of drop-off centres).
- Develop facilities to form part of an integrated waste management system and avoid stand-alone entities. Any service expansion will have an impact on the existing solid waste management system in the municipality. Such an expansion should be carefully planned, designed and managed to ensure that the entire solid waste management system becomes more sustainable over the longer term.

M.4.3.1 Materials Recovery Facilities

A Materials Recovery Facility (MRF) is a specialised plant that receives, sorts and prepares recyclable materials for end-user manufacturers or recycling companies.

- A clean MRF accepts recyclable materials that have already been separated at the source from non-recyclable municipal solid waste. The recyclables are mixed and need to be sorted further before being baled.
- A dirty MRF accepts municipal solid waste that has not been sorted according to recyclable and non-recyclable materials. At the dirty MRF, the recyclables are separated from the non-recyclable municipal solid waste, sorted further and baled.

Waste is usually brought to MRFs by waste collectors (local entrepreneurs) and community members. After sorting, the recyclable materials go to relevant end-user manufacturers or recycling companies. Residual waste (that remains after sorting) is removed by the local municipality and usually disposed of at landfill sites.

MRFs can use simple technology such as sorting tables and conveyor belts, and these can potentially employ high numbers of low-skilled staff to do the sorting and baling. Sophisticated machinery can also do the sorting with only one or two skilled staff members employed to operate the system. The level of mechanisation required at a MRF will therefore depend on the type of waste handled, the need for job creation and the available funds. Indicative thresholds regarding volumes handled, operational areas and level of automation are provided in the *SALGA Good Practice Guide to: Waste Transfer Stations, Materials Recovery Facilities and Buy-back centres.*[10]

Figure M.10: Recyclables offloaded at a clean MRF (L) and sorting tables at a dirty MRF (R)

M.4.3.2 Buy-back centres

Buy-back centres are run as small businesses that buy recyclable materials from community members or waste collectors (local entrepreneurs). The waste is then sorted, crushed and/or baled and sold to members of the recycling industry. Buy-back centres are usually viable in low-income areas, where community members are rewarded for collecting recyclables. However, with more waste collectors active in middle- and high-income neighbourhoods, buy-back centres may become viable in these areas. Buy-back centres for recyclable waste can be set up at shopping malls, parks, schools and churches. Mobile buy-back centres are sometimes used to put facilities within reach of more users and to shorten the distances for those making a living from collecting and selling recyclables. Guidance on specifications for buy-back centres is provided in the *SALGA Good Practice Guide to: Waste Transfer Stations, Materials Recovery Facilities and Buy-back centres.*[11]

M.4.3.3 Transfer stations

A waste transfer station is a facility where solid waste is transferred from collection vehicles to more appropriate long-haul vehicles before the waste is transported over longer distances (exceeding 20 km) to dirty MRFs, treatment facilities or for final disposal at landfills. The purpose of these stations is to reduce the transport unit cost of collection vehicles (by achieving more cost-effective payloads) and to achieve quicker turnaround times for collection vehicles. Decide on the number of transfer stations and the degree of sophistication required according to the volume of waste generated, the collection system implemented and the distance to the disposal site. For further assistance, consult the *SALGA Good Practice Guide to: Waste Transfer Stations, Materials Recovery Facilities and Buy-back centres.*[12] A break-even point can be calculated where it will be more economical to build a waste transfer station than to haul waste materials over long distances. In the equation below, the waste transfer station (WTS) cost refers to the cost to build, own and operate the transfer station (in R/tonne) and the distance of the haul refers to a two-way distance (in km).

Equation M.5: Break-even point for transfer station

Cost of Direct haul = [distance (km) x trucking cost (R/km)] / direct haul payload (tonnes)

Cost of Transfer = [WTS cost (R/tonne) + distance (km) x trucking cost (R/km)] / transfer haul payload (tonnes)

M.4.3.4 Central collection points

A central collection point is often used in areas where poor access hinders the provision of kerbside collection services. For example, the layout or road conditions in high-density informal settlements may not be suitable for use by heavy waste collection vehicles. Central collection points can be combined with buy-back centres (see Section M.4.3.2) or drop-off facilities (see Section M.4.3.5) in areas where kerbside collection for recyclables is not implemented.

Waste is usually brought to central collection points by waste collectors (local entrepreneurs) and community members. The locality of the collection point is critical to ensure easy access for all users. Refer to Section F for guidance on neighbourhood layout. Where necessary, ramps must be provided to facilitate easy access for placing the waste inside the containers.

M.4.3.5 Drop-off facilities

Drop-off facilities are similar to buy-back centres, but these facilities are not managed as businesses. Recyclables are dropped off without the expectation to receive any form of compensation for either the effort to bring in the waste or the separated recyclables itself. Garden refuse sites are examples of drop-off facilities.

When deciding on the need for drop-off facilities in a development, consider providing multi-purpose drop-off sites. A multi-purpose drop-off facility would typically take garden waste as well as paper, plastic, glass and cans. The reduced number of household trips to drop off waste does not only add to the convenience of users, but will ultimately result in a smaller carbon footprint. Drop-off facilities for recyclable materials can be set up at shopping malls, parks (see Section G), schools and churches, but should be well maintained.

Figure M.11: Examples of multi-purpose drop-off facilities

M.4.3.6 Treatment / Recovery facilities

The recovery of waste resources, as referred to in the waste management hierarchy (Figure M.2), includes various waste treatment options such as organic waste composting or digesting biodegradable wastes to produce usable gases. Waste treatment options may include the following:

- Advanced biological treatment (including in-vessel composting and anaerobic digestion)
- Advanced thermal treatment (including pyrolysis, gasification and incineration)
- Incineration of unprepared - raw or residual –municipal solid waste
- Mechanical biological treatment (separation and then treatment/ treatment and then separation)
- Mechanical heat treatment

When deciding on the possible treatment of waste, consider the following:

- Most technologies are waste-stream-specific and therefore require source-separated waste to function optimally. Waste that has not been separated at source will have to be separated at a MRF or will have to be pre-treated before it can be processed.
- Alternative treatment technologies are expensive to implement relative to disposal at landfill and require economies of scale to be feasible.
- The residues from alternative treatment technologies are mostly concentrated waste streams with higher risk levels than untreated municipal solid waste. These waste streams therefore require classification and assessment prior to disposal at landfills.

Depending on the size of the facility and the type of treatment at the site, treatment facilities would most likely require a waste management licence. An Environmental Impact Assessment (EIA) will have to be done in terms of the NEM:WA. The key issues that should be considered in the EIA include emissions, dust, odour, flies, vermin and birds, noise, impact on water resources and visual intrusion.

These facilities may also generate additional traffic in an area. For a 50 000 tonne per annum capacity plant up to 30 waste collection vehicles per day can be anticipated.

M.4.3.7 Landfill sites

Landfilling is the least desired option for disposal of waste. Only waste with no recycling or recovery alternative should be disposed of at landfills. The design of landfill facilities falls outside the scope of this Guide, but the following should be noted when designing a waste management service in a neighbourhood:

- Make provision for final disposal of residual waste, irrespective of other waste diversion strategies and technologies implemented, because all treatment technologies have a portion of residual waste that needs to be disposed of.
- Follow the specifications for disposal of pre-classified and listed waste, as well as the requirements for classification of waste that is not pre-classified to ensure proper disposal according to the *National Norms and Standards for Disposal of Waste to Landfill*[13] set in line with the NEM:WA. There are specified waste acceptance criteria for each class of landfill. For example, no tyres (quartered, shredded or otherwise) may be disposed of at a landfill. There are also restrictions on the disposal of garden waste at landfills and alternative facilities are required for garden waste disposal.

For detailed formulae and explanations on how to calculate landfill site life, the *Minimum Requirements for Waste Disposal by Landfill*[14] can be consulted.

Figure M.12: Different vehicles are used for the disposal of solid waste at landfill sites

Glossary, acronyms, abbreviations

Glossary

Baling
Baling is the process to compress or bundle waste material into a block or bale which can then be secured by plastic or wire strapping. Bales are easy to store and transport.

Building and demolition waste
Waste, excluding hazardous waste, produced during the construction, alteration, repair or demolition of any structure. It includes rubble, earth, rock and wood displaced during construction, alteration, repair or demolition. Also sometimes referred to as builders' rubble.

Business waste
Waste that emanates from premises that are used wholly or mainly for commercial, retail, wholesale, entertainment or government administration purposes.

Buy-back centre
A facility where recyclable waste materials can be exchanged for money, food or clothing. Buy-back centres purchase recyclable waste from collectors (formal and informal) of waste, bale the waste and sell it on to recycling industries.

Compaction
Waste compaction is the process of reducing waste in size by means of compaction. This is done so that more waste can be stored in the same space. Waste compaction is often done in the waste collection vehicle, while a more thorough compaction is done at the landfill to conserve valuable airspace and to extend the landfill's life span. The amount this volume is reduced by is called the compaction ratio. For example, a compaction ratio of four to one indicates that four times the volume of compacted waste can be placed in the same storage space occupied by the non-compacted waste.

Composting
A controlled biological process in which organic materials are broken down by micro-organisms.

Container
A disposable or reusable vessel in which waste is placed for the purposes of storing, accumulating, handling, transporting, treating or disposing of that waste. This includes bins, bin-liners and skips.

Development contribution
A financial contribution which an applicant for development is required to make to fund the provision of engineering services to the land to be developed.

Disposal
The burial, deposit, discharge, abandoning, dumping, placing or release of any waste into, or onto land.

Domestic waste
Waste, excluding hazardous waste, that emanates from premises that are used wholly or mainly for residential, educational, health care, sport or recreational purposes.

Garden waste
Organic biodegradable waste material generated from the likes of a typical garden.

General waste
Waste that does not pose an immediate hazard or threat to health or the environment and includes:
- Building and demolition waste
- Business waste
- Inert waste

Hazardous waste
Any waste that contains organic or inorganic elements or compounds that may have a detrimental impact on health and the environment, owing to the inherent physical, chemical or toxicological characteristics of that waste.

Incineration
Any method, technique or process to convert waste to gases and residues by means of oxidation.

Litter
Waste products that have been disposed of improperly, without consent and in an inappropriate location.

Materials Recovery Facility
A processing facility where waste materials are sorted and prepared for sale or transport to end users.

Medical waste
Waste generated by hospitals, clinics, nursing homes, doctor's offices, medical laboratories, research facilities and veterinarians, which is infectious or potentially infectious.

Minimisation
The avoidance of the amount and toxicity of waste that is generated and, in the event where waste is generated, the reduction of the amount and toxicity of waste that is disposed of.

Organic waste
Waste of biological origin that can be broken down, within a reasonable amount of time, into its base compounds by micro-organisms and other living things and/or by other forms of treatment.

Recovery
The controlled extraction or retrieval of any substance, material or object from waste.

Recycling
A process of reclaiming waste for further use, which involves the separation of waste from a waste stream and the processing of that separated material as a product or raw material.

Reuse
Utilising the whole, a portion of or a specific part of any substance, material or object from the waste stream for a similar or different purpose, without changing the form or properties of such substance, material or object.

Solid waste
Waste of a solid nature generated by a person, business or industry.

Sorting
The authorised separation of solid waste materials for the purpose of recycling or disposal, either at the source of generation or at a solid waste management facility.

Storage
The accumulation of waste in a manner that does not constitute treatment or disposal of that waste.

Treatment
Any method, technique or process that is designed to
- change the physical, biological or chemical character or composition of a waste,
- remove, separate, concentrate or recover a hazardous or toxic component of a waste,
- destroy or reduce the toxicity of a waste,

in order to minimise the impact of the waste on the environment prior to further use or disposal.

Waste
Any substance, material or object that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of by the holder of that substance, material or object, whether or not such substance, material or object can be reused or recycled.

Waste management services
Waste collection, treatment, recycling and disposal services.

Waste transfer facility
A facility that is used to accumulate and temporarily store waste before it is transported to a recycling, treatment or waste disposal facility.

Waste treatment facility
Any site that is used to accumulate waste for the purpose of storage, recovery, treatment, reprocessing, recycling or sorting of the waste.

Acronyms and abbreviations

DEA	Department of Environmental Affairs
EIA	Environmental Impact Assessment
IDP	Integrated Development Plan
IWMP	Integrated Waste Management Plan
MRF	Materials Recovery Facility
NEM:WA	National Environmental Management: Waste Act
SALGA	South African Local Government Association
SAWIS	South African Waste Information System
SDG	Sustainable Development Goal
SMME	Small, Medium and Micro-sized Enterprise
WTS	Waste transfer station

Endnotes

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Section N
Electrical energy

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 N

Electrical energy

The Neighbourhood Planning and Design Guide

Table of contents

N.1 Outline of this section

N.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 electrical energy in this system. The aspects addressed in this section play an essential role in achieving the vision for human settlements outlined in **Section B** since electricity supply significantly increases the quality of living environments. In particular, the provision of good quality and sustainable electricity services could play a key role in addressing the challenges facing human settlements as a result of climate change.

Grid-based electricity has historically been the preferred option for energy provision because of its advanced level of development. However, the introduction of embedded distributed generation and off-grid systems, and the drive to use clean energy sources, provide new options for electrifying new or unserved communities.

N.1.2 Content and structure

This section (Section N) is structured to support effective decision-making related to the provision of electricity. The decision-making framework is outlined in Figure N.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 electricity 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 electricity 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 electricity provision that are available for consideration.

Design considerations

Guidelines to assist with the design of electricity systems.

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 N.

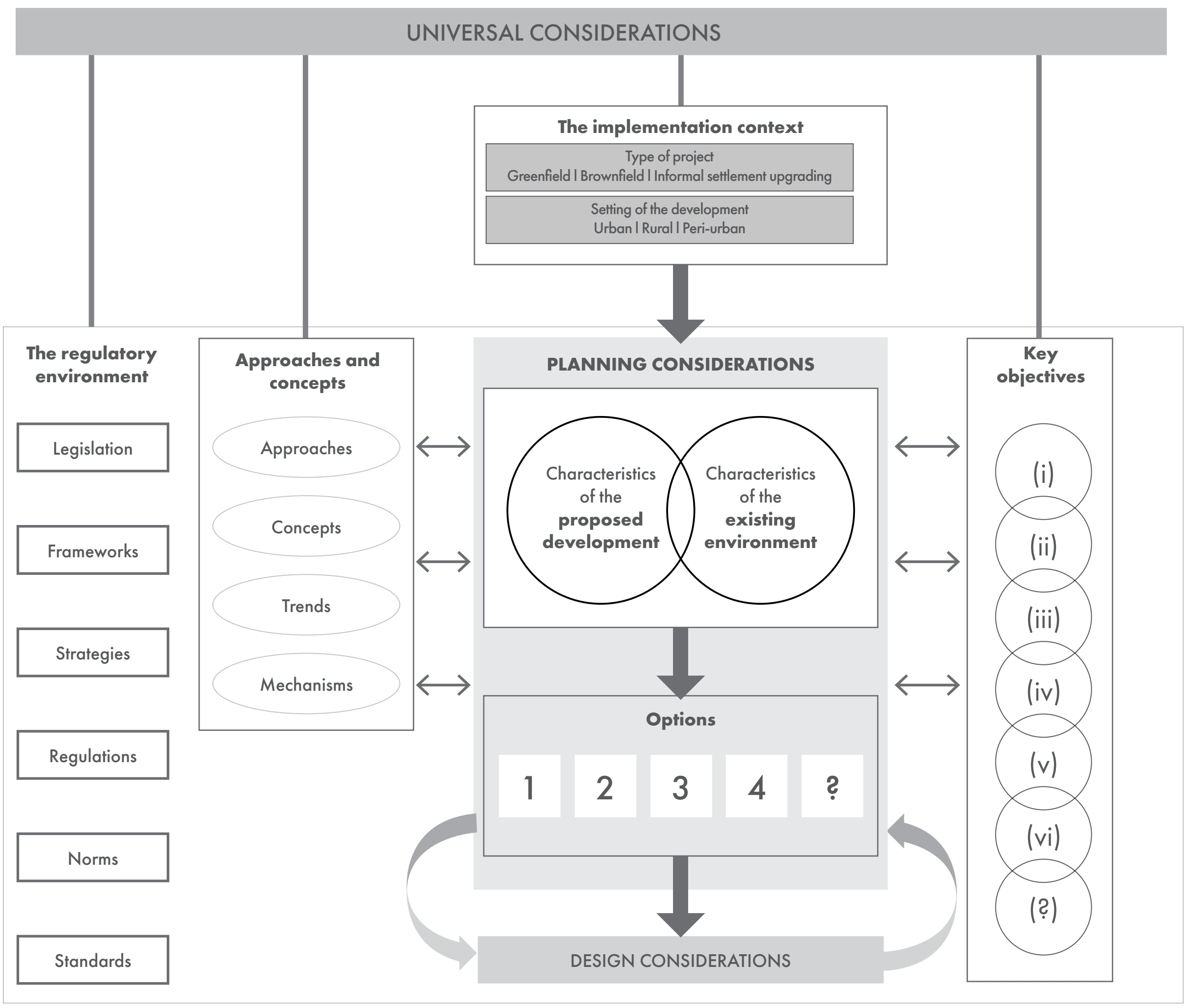

Figure N.1: A framework to assist with planning and design decisions

N.2 Universal considerations

N.2.1 The regulatory environment

The provision of electricity and energy is governed by, amongst others, the Electricity Regulation Act of 2006, the National Energy Act of 2008 and the National Environmental Management Act of 1998, together with their respective amendments. A key document that guides long-term planning for the provision of electricity is the Integrated Resource Plan for Electricity 2010 - 2030, which is intended to be a living document that is updated on a regular basis.

In addition to the above, a range of policies, strategies, plans etc. guide the provision of electricity in South Africa. Some of these documents are briefly summarised below. They are not discussed in detail, so it is important to consult the relevant documentation before commencing with any development.

(i) The White Paper on the Energy Policy of the Republic of South Africa, 1998

The White Paper on the Energy Policy of the Republic of South Africa places an emphasis on the following five key objectives relating to the energy sector as a whole:

- Increasing access to affordable energy services
- Improving energy governance
- Stimulating economic development
- Managing energy-related environmental impacts
- Securing supply options through diversity

(ii) White Paper on Renewable Energy, 2003

The White Paper on Renewable Energy provides a framework for the inclusion of largely untapped naturally available renewable resources into South Africa's energy mix. This White Paper outlines the government's vision, policy principles, strategic goals and objectives for promoting renewable energy such as solar, hydro, biomass and wind in South Africa. This document is complemented by the *Integrated Resource Plan*[1].

(iii) National Climate Change Response White Paper, 2011

The National Climate Change Response White Paper focuses on mitigation and adaptation approaches for the national government to respond to climate change in a manner that ensures resilient, internationally competitive and equitable economic development. The policy identifies the use of renewable energy resources as an important mitigation option in achieving government's greenhouse gas emissions goals.

(iv) Electricity Basic Support Tariff (Free Basic Electricity) Policy, 2003

The purpose of this policy is to support indigent households in meeting their basic energy needs through the provision of a limited amount of electricity to them.

(v) Free basic alternative energy policy: Households energy support programme, 2007

This policy complements the Free Basic Electricity Policy in that it is intended to provide aternative energy to indigent to households in areas that have not been electrified.

N.2.2 Key objectives

Based on the focus areas and objectives highlighted in the policy documents referred to in Section N.2.1, the following three key objectives can be extracted that should be achieved when implementing the guidelines that follow:

- Promote energy security through diversity of electricity supply
- Ensure energy equity by supporting access to affordable electricity services
- Support environmental sustainability by implementing energy systems that minimise negative impacts on the environment and people

N.2.3 Approaches and concepts

N.2.3.1 Grid-based electricity

Grid-based electricity is the supply of electricity coming from the interconnected national electricity grid. This form of electricity can come from a wide range of supply options such as nuclear, coal and renewable energy resources in centralised power stations.

N.2.3.2 Off-grid electricity

The supply of electrical services in the form of a localised grid that is not tied to the national electricity grid is referred to as off-grid electricity (or sometimes non-grid electricity). The supply options in this type of service are mainly renewable energy resources that are usually location specific.

N.2.3.3 Microgrid

A microgrid (also referred to as a minigrid) is a small-scale electricity generation and distribution system that serves a group of localised customers, or loads. A microgrid can either operate as an autonomous system that is not connected to the national electricity grid, or it could be linked to the grid but be able to disconnect and connect depending on circumstances. A microgrid could therefore receive electricity from the grid, and if this is not possible, or if other sources of electricity are utilised, it could operate independently, which is referred to as island mode. Minigrid systems usually make use of renewable energy sources such as solar or wind.

N.2.3.4 Embedded (electricity) generation

Embedded generation refers to the small-scale production of electricity (outside of the national grid), and the introduction of this electricity to the distribution network. Renewable energy sources, usually located close to the place of consumption, are commonly utilised.

N.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 regarding the provision of energy services. Also refer to Section D.2.1 (Type of development) and Section D.2.2 (The setting/location of the planned development).

N.2.4.1 The type of development

(i) Greenfield development

Greenfield projects can theoretically accommodate most types of electricity provision. The deciding factor would normally be the income level of the anticipated residents of the new development, and the availability of electricity supply.

(ii) Brownfield development

The types of electricity systems that could be provided on brownfield sites would be influenced by the nature of the existing physical and socio-economic environment within which the development will be located. For instance, infill developments, retrofitting and the subdivision of large residential stands may all require different types of systems depending on the availability of electricity supply.

(iii) Informal settlement upgrading

Informal settlement upgrading projects are usually complex undertakings that require extensive community participation, specifically with respect to the level of services and infrastructure to be provided. Acceptability and perceptions would be important factors to address when making decisions regarding electricity provision.

N.2.4.2 The setting of the development

(i) Urban

Urban settings can take on different forms, and therefore developments will vary in nature. Urban areas include central business districts, residential suburbs, informal settlements, and what used to be referred to as townships, and this will influence the type of electricity system to be provided.

(ii) Peri-urban

Given the transitional nature of peri-urban areas, the nature of developments will vary considerably, and so will the manner in which electricity is provided.

(iii) Rural

Development sites in rural areas will vary in nature depending on the location, for instance whether it is situated in a rural town or a dispersed settlement. The manner in which electricity is supplied will therefore also vary.

N.3 Planning considerations

This section deals with the planning for the provision of electricity. 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 electricity supply options based on a thorough understanding of the context within which the planned development will be implemented.

Decisions regarding electricity supply have to be informed by a thorough understanding of the features and requirements of the proposed project, and of the context within which the planned development will take place. 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 should be identified.

This section outlines a range of questions that need to be answered and factors that have to be considered to inform decisions regarding the electricity system to be provided as part of a development project.

N.3.1 Characteristics of the proposed development

Decisions regarding electricity provision 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. Issues that should be considered are discussed below.

N.3.1.1 The nature of the proposed development

Various factors related to the nature of a development could influence decisions regarding the provision of electricity services. For instance, mixed-use, mixed-income projects, and projects that are primarily residential in nature, would need different types and sizes of substations and different electrical network capacities. 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 electrical capacity provisions.

N.3.1.2 The potential residents of the development

Decisions related to electricity provision need to be guided by information regarding the potential residents. Usually, the identities of the actual residents are not known when a development is planned and designed. It may be possible to make assumptions regarding the possible nature of the future residents by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to try to establish the following as far as possible:

- The total number of residents that would have to be accommodated, taking into consideration that actual numbers may be higher than anticipated due to the fact that the provision of houses and services may attract more people than originally planned for. As the population of the area increases, there is likely to be an increase in demand for electricity.
- The number of households and the range of household sizes. This will indicate how much electricity may have to be provided.

- Income and employment levels and spending patterns. This would, for instance, indicate to what extent the households can afford to pay for electricity services and hence would help to plan and design a system that can accommodate the provision of free basic electricity.

N.3.2 Characteristics of the existing environment

To decide on the technology and level of service to be provided, a clear definition of the area to be developed is necessary in order to appropriately scope the required electricity services. Decisions regarding electricity provision need to be guided by an assessment of the context within which the development will be located.

G.3.2.1 The physical location of the proposed project

Constraints and opportunities posed by the site could influence the way in which electricity is provided. The existing features of the area and immediate surroundings (built and natural environment) of the proposed development need to be considered when planning for both grid-based and off-grid electricity systems. Aspects that need to be considered are briefly outlined below.

(i) Topography

The topography of the project site is an important factor that should be considered when making decisions regarding the layout of the development, and as such it will also guide decisions regarding the provision of electricity services for the neighbourhood being developed. Various physical characteristics of the environment, e.g. the slope of the site, streams, hilly terrain and rocky outcrops, will influence the design and installation of infrastructure such as overhead lines, underground cables, substations, wind farms, and solar PV panels.

(ii) Climate

The micro- and macro-climate conditions of the site will have an impact on the type of electricity system suitable for deployment. The site should be physically inspected to assess the climatic changes at different times of the day, preferably even at different times in the year. Physical inspections will provide clues about the suitable location of the electrical infrastructure. The following questions need to be answered:

- Is the site exposed to prevailing winds? Is the wind direction seasonal? This information would assist in deciding whether a wind farm would be a feasible option, and, if so, where it should be located.
- Where does the sun rise and set in summer and winter? Be aware that there may be external features that influence sun penetration on the site, such as a nearby mountain, hill, tree, or building.

(iii) Geotechnical characteristics

The type of soil can sometimes necessitate the use of specialised construction methods or materials. It can also mean that certain areas of the site might not be suitable for the installation of electrical infrastructure. Civil structures may need to be reinforced for different supply and/or network infrastructure e.g. overhead line towers/poles, solar PV installations and wind turbines. The following questions need to be answered:

- What is the soil condition and quality?
- Is the site part of or close to a dolomitic area?
- Was the site used for mining and exploration in the past?

- Is the site subject to seasonal flooding?
- Are there obstacles that would limit sun penetration that cannot be removed?

(iv) Landscape and ecology

The physical features of the landscape could have a substantial impact on the types and positioning of biogas, solar and wind systems, and electrical lines. If the development is located in or near an ecologically sensitive area, there may be restrictions that may influence the positioning (and ease of construction) of the electrical infrastructure. Ensure that information is collected regarding 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 approvals from various government departments.
- Wetlands, surface water bodies or other ecologically sensitive areas on or near the site.
- Endangered or protected animal 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.

(v) Existing buildings on the site

If there are existing buildings on the proposed development site, they can be viewed as either presenting opportunities or constraints. In certain cases, existing buildings could be incorporated into the development by converting them into housing or social facilities. If such buildings are converted, the electricity supply and reticulation network in the area should be planned and designed to be able to accommodate such buildings.

N.3.2.2 Available infrastructure / services

Neighbourhood developments often create additional demand for services and therefore have a potential impact on existing services and infrastructure. The following needs to be established:

- What electrical infrastructure (bulk and local) is available close to the new development?
- What is the proximity of the neighbourhood to existing and planned electrical network infrastructure?
- How far is the neighbourhood from Eskom or municipal transmission/distribution networks?
- What is the status of planned transmission/distribution networks for the area?
- Does existing infrastructure have enough capacity to accommodate the new development?
- Can the new development be linked to existing infrastructure?
- If yes, what is the cost of extending existing transmission/distribution networks for the neighbourhood and/or other proposed developments in the area?
- The cost of off-grid energy supply (wind, solar PV, hydrogen, diesel, biogas and natural gas) and the associated network infrastructure relative to grid-based electricity supply.

It might be necessary to undertake field visits to confirm and complement existing network data for infrastructure such as network equipment, historical loading and performance.

N.3.2.3 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. Where appropriate, the community for whom the proposed project is developed must be involved in the decision-making process from the outset to ensure their concerns are understood and taken into consideration (See Section E).

It is also important to acquire information regarding the socio-economic features of the neighbouring or surrounding communities. This will provide some indication of the Living Standard Measure (LSM) of the new development, and therefore the electricity system required. 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 will be living in the planned neighbourhood?
- What is the average size of households in the area?
- What is the income profile of the residents and which living standard measure do households fall under?
- What is the employment profile of the residents?

N.3.2.4 Existing plans and developments

Most of the information and data required to assist with planning electricity services could be obtained from relevant departments within municipalities. As a starting point, a significant amount of raw and processed data can be extracted from the following:

- Spatial Development Frameworks (SDFs)
- Local Economic Development (LED) plans
- Regional electrification plans
- Integrated Development Plans (IDPs)

Demand will primarily be driven by the location and type of development, the existing and planned population demographics as well as the size and socio-economic characteristics of the development. When electricity services have to be provided for a range of population demographics (in particular where low-income households are dominant), the increased demand and consumption after electrification should be taken into consideration during the planning phase.

N.3.3 Electricity systems options

N.3.3.1 Factors to consider

Planning for electricity services for a development is in essence based on capacity requirements (i.e. active power (kW) and not necessarily the energy (kWh)). Due to the stochastic nature of specific household electricity usage, statistical methods are used to derive these capacity requirements (Figure N.2). A key parameter that results from these statistical methods is that of after diversity maximum demand (ADMD). ADMD is the simultaneous maximum demand of a group of households divided by the number of consumers, expressed in apparent power (kVA) (which is very similar to kW but adjusted for the expected power factor). ADMD is discussed in more detail in Section N.4.

A key decision that needs to be taken is whether a grid-based or off-grid electrical service will be used (or a combination of the two). These options are discussed next.

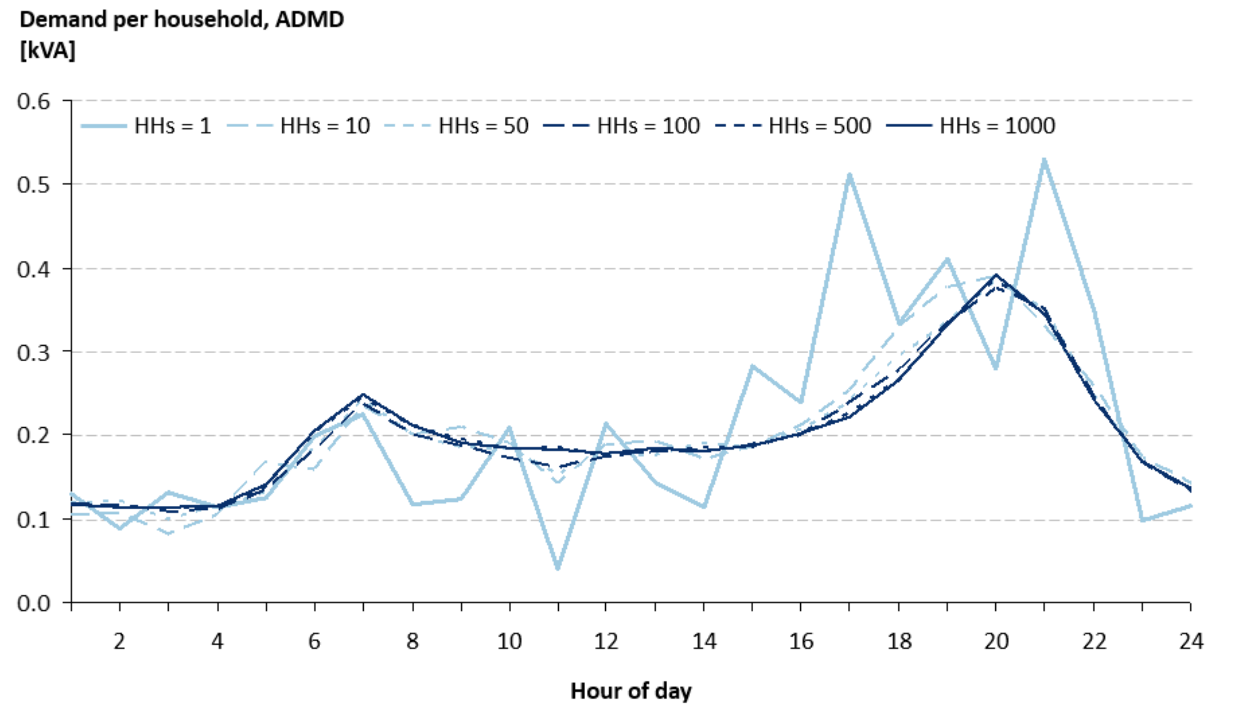

Figure N.2: Electricity demand on a representative day for 1 to 1000 similar households to demonstrate ADMD

N.3.3.2 Grid-based medium voltage and low voltage options

(i) Electricity planning for medium and low voltage networks

There is an important difference between planning a medium voltage (MV) and low voltage (LV) electricity service. MV involves large networks, and MV planning therefore focuses on bulk capacity, while LV planning relates to electricity at neighbourhood and household levels.

Whether the provision of electricity is via a grid-based or an off-grid service, it is recommended that common, standardised MV and LV components are used. This will ensure that an off-grid neighbourhood will be able to connect to the grid if needed without difficulty.

A high-level summary of MV and LV technology options available is provided in Table N.1. The information provided can be used to assist in making decisions regarding the technologies available and their suitability for different types of neighbourhood development.

For high-density (HD) urban applications, conventional three-phase systems are the only appropriate technology (combined with small-scale embeded generation, demand side response and/or storage, where appropriate). For rural networks, any system may be appropriate, depending on local conditions - even conventional three-phase systems may be used on a small scale where HD load pockets exist.

Table N.1: MV/LV options for grid-based electricity depending on the type of development (adjusted from various sources[2,3,4])

Type of development	MV technology[1]	LV technology[2]
High-density, high income urban areas High-density, lower-income urban areas	• Buried three-phase MV cable • 11 kV or 22 kV • Overhead three-phase • 11 kV or 22 kV	• Buried three-phase cable • Overhead three-phase (could use single-phase LV tee-offs)
Medium density (suburb, lifestyle)	• Buried three-phase MV cable • 11 kV or 22 kV	• Buried three-phase cable
Low-density, peri-urban, smallholdings	• Buried three-phase MV cable OR overhead three-phase MV • 11 kV or 22 kV	• Overhead dual-phase in higher-density areas (with single-phase tee-offs) • Single-phase in low-density areas
Rural networks (incl. rural electrification)	• Overhead three-phase MV (backbone) • 22kV preferred • Minor tee-offs: phase-to-phase • SWER tee-offs in very low-density areas • Phase-to-phase and SWER tee-off loading limited to ≤ 400kVA and ≤1% voltage unbalance per tee-off • MV induced voltage unbalance ≤0.8% and ≤1.5% for predominately three-phase and single-phase networks respectively	• Overhead dual-phase in higher-density areas • (with single-phase tee-offs) • Single-phase in low-density areas • Three-phase to large end-users (pumping loads etc.)

[1] MV = nominal voltages greater than 1 kV but lower than 44 kV; in practice these would be 11 kV, 22 kV and 33 kV.

[2] LV = 230 V single-phase to neutral, 400 V phase-to-phase, 460V phase to phase-to-dual phase (230V phase to neutral).

When planning MV and LV electricity services, it is important to also consider aspects related to sub-transmission level grid networks. Sub-transmission level networks are below transmission level but above MV/LV levels (typically 44 kV, 66 kV or 88 kV). Factors to consider include the following:

- The provision of sub-transmission network infrastructure involves long lead times, substantial servitude requirements, and, if not planned for in good time, will result in significantly increased costs as a result of the possible deployment of sub-optimal technologies, e.g. buried HV/MV cables and compact (sometimes underground) substations.

- The HV/MV substation(s) that will be used as the source from which the MV/LV grid-based electricity is going to be supplied should be known. It should then be determined if the substations have sufficient capacity available, or whether upgrades will be required. Upgrades could include adding transformation capacity, bus-bar extensions, an additional feeder bay or even a new HV/MW substation and overhead line(s).

The construction periods for MV grid infrastructure are shorter than for sub-transmission infrastructure, but can still be significant. The following should be considered:

- MV overhead lines and buried cables require servitudes and therefore the planning of routes should be sufficiently integrated with other aspects of spatial planning and design, e.g. roads, subdivisions and public open space.
- The number of MV feeders, feeder lengths and cable/conductor sizes is dependent on the magnitude of expected demand as well as the spatial characteristics of the neighbourhood.

(ii) Small-scale embedded generation, demand side response and energy storage

Small-scale embedded generation (SSEG), aggregated demand side response (DSR) and/or energy storage can be summarised as follows:

- SSEG complements existing network technologies and could also be deployed at household or community levels for partial/full self-supply of electricity needs. This could include solar PV panels, micro-hydro, and wind or biomass/-gas supply technologies. These would then be connected at LV level via either single-phase or three-phase connections.
- DSR at neighbourhood level involves the management of the demand placed on an electricity network by all the household appliances combined (the aggregate demand) at specific times to reduce the electricity required, rather than having to increase the electricity supply to meet peak demands.
- Energy storage is a useful mechanism that could be used to ensure that a particular network has a stable and reliable electricity supply. It involves the storage of electricity during periods when demand is low, and the utilisation of the stored electricity during peak times when the demand for electricity is high.

(iii) Reliability of supply

The reliability of electricity supply is an important factor to consider when designing grid-based electricity services. For sub-transmission as well as MV/LV networks, the System Average Interruption Duration Index (SAIDI) is usually used to measure reliability. The SAIDI is an indication of the average duration of customer interruptions within a particular area. A good SAIDI means that customers will be without electricity for shorter periods of time.

In addition to the reliability of a service, the cost of unreliability (the cost of customer interruptions) should also be considered. This is referred to as the cost of unserved energy (COUE). COUE can be calculated at a high level for a homogenous group of households, or it can be disaggregated into LSM categories as a function of the demographics for the neighbourhood. Neighbourhoods with higher concentrations of higher LSM level customers would have a higher COUE, whilst electrification of settlements in rural areas and informal settlements would have a lower COUE. This is an important planning consideration, as it defines the acceptable level of energy service to the proposed development (the reliability of the service). As a result, it has direct implications for the required investment in network infrastructure. For more information, refer to the *Distribution Network Code*[5].This code sets the basic rules of connecting to the distribution system and specifies the technical requirements to safeguard the safety and reliability of the distribution system to ensure that all users of the system are treated in a non-discriminatory manner.

N.3.3.3 Off-grid technology options

(i) Resource assessment

To guide decisions regarding off-grid technologies, information regarding potential energy sources and resources is required. An assessment should be conducted that would provide answers to the following questions:

- Which energy resources are available and in what quantity?
  - Non-renewable e.g. coal, natural gas, diesel/petrol
  - Renewable e.g. wind, solar, biomass/biogas, water
- Which technology can be used to produce electricity from these energy resources?
  - Solar: concentrated solar power (CSP), solar photovoltaics (PV)
  - Wind: Wind turbines
  - Waste/animal residue/biomass: gasification systems, steam turbines, engines
  - Water: turbines, electrolysis (hydrogen)
- What are the costs for producing energy with these technologies (now and in the future), i.e. life cycle costs, levelised cost of electricity including capital expenditure, operational expenditure and other costs?

Guidance on the planning of off-grid electricity services is available in the IEC/TS 62257 series[6].

(ii) Microgrids

Microgrids can be implemented in both grid-based and off-grid electricity systems. However, they are predominantly used in off-grid applications, and mainly for rural electrification. See Section N.2.3.3 for a brief description of microgrids.

A microgrid system could be an appropriate option under certain circumstances for the following reasons:

- They contribute to the drive towards clean energy and resilient infrastructure.
- They are less susceptible to grid-based electricity outages.
- By enabling the use of locally sited energy resources such as liquid fuels, wind, solar, hydro or biomass/biogas, microgrids may diversify a neighbourhood's energy portfolio.

During the microgrid planning phase, it is important to carry out detailed feasibility studies to ensure the investment is justified. A substantial initial capital investment is required, which can vary widely depending on the specific circumstances of the project. The lifetime cost of the system should also be carefully assessed to ensure that long-term financial commitments with respect to ongoing management and maintenance are taken into consideration. These costs need to be considered in conjunction with potential cost savings that could be achieved over a period of time, and the revenue that the system will generate.

A comprehensive assessment needs to be conducted to assist in determining the return on investment and bankability (e.g. attractiveness in terms of cashflow, future earnings, probability of securing financing etc.) of the project to enable customers/investors to make informed decisions about the viability of the microgrid project. The advantages and disadvantages of different financing options also need to be evaluated. Funding sources may include customers themselves, private investors or other third parties, government departments and entities, local utilities or municipalities, or a combination of these.

It is important to note that financial viability (bankability) is not always the only criterion that should be taken into consideration when deciding whether or not a microgrid system should be provided. Other factors that could influence decisions include the proximity of the proposed development to the existing grid, the impact of grants and subsidies on the viability of the system, the need to be (or not be) independent of the grid, and access to reliable energy sources. In some cases, minigrid systems may be the most appropriate way of providing rural communities with electricity.

N.4 Design considerations

Various software tools are available to assist with the planning and design of electricity systems, and therefore this section does not provide detailed guidance on design calculations.

The Department of Energy has provided guidelines on electrification of informal settlements[7], and the primary consideration is that the design of the grid for servicing informal settlements must comply with planning and design aspects of NRS 034-1[8], the quality of supply specifications of NRS 048[9], and the quality of service specifications in NRS 047[10].

N.4.1 Demand forecasting

Demand forecasting is strongly dependant on the geospatial characteristics as well as demographics and socio-economic characteristics of the neighbourhood development. A number of tools are available that take all the variables into consideration to assist with geospatial demand forecasting. A number of tools have been developed that are applicable specifically to the South African context[11, 12].

A demand forecast for 20 years in 5-year increments and with the lowest possible geographical resolution would usually be necessary. Hourly geospatially disaggregated demand profiles would allow for the determination of the ADMD for the neighbourhood and the accurate design of network infrastructure. The demand can be established on the basis of collected data or applied load sub-classes (based on the number of households, locations and demographics). The sum of these demand profiles will provide the overall demand forecast.

Typical load classes are defined in the *Geo-based Load Forecast Standard*[13] as well as in the NRS 034 series[14]. More information about load classes and the expected demands associated with the load classes is available in the *Distribution Network Planning Standard*[15] and NRS 048-2:2003 .

To account for uncertainty in demand growth, a probabilistic approach to demand forecasting is useful. This means that the possibility of SSEG being incorporated into the electricity service is taken into account when determining demand.

N.4.2 Small-scale embedded generation

As a guideline, the maximum size of an individual generator in an LV network should not exceed 25% of a customer's maximum demand (if on a shared feeder) and no more than 75% of a customer's maximum demand (if on a dedicated feeder). For further information on the integration of SSEG into LV networks, see NRS 097-2-3:2014[17] and the *Grid Connection Code for Renewable Power Plants Connected to the Electricity Transmission System or Distribution System in South Africa*[18]. The purpose of this code is to specify minimum technical and design grid connection requirements for renewable power plants that are connected to, or intend to connect to, the South African electricity grid or distribution system.

All SSEG installations should be either licensed or registered with NERSA. It is also essential to involve the electricity service provider (Eskom or the municipalities) in decisions when considering the implementation of a SSEG system. The following documents are relevant:

- *Requirements for SSEG - Conditions and Application Process to Become a Solar PV Embedded Generator:* The purpose of this document is to provide information regarding the process to follow when connecting solar PV embedded generation to a municipal electricity network.
- *Application for the Connection of Solar PV Embedded Generation:* This is a template application form for the connection of an inverter-based solar photovoltaic generation system to the electrical grid of a municipality.
- *Contract for Embedded Generation:* This is a template contract that clarifies the terms, conditions, rights and obligations of different parties regarding the connection of the customer's SSEG system to the municipal electricity grid.

N.4.3 Quality of electricity supply

The quality of the electricity supplied to an area needs to meet certain minimum standards. Under normal conditions, electrical network equipment should not be loaded beyond acceptable thermal and fault-level ratings as specified in NRS 034-1[19]. Only during abnormal operating conditions should network equipment be operated beyond design ratings, and then for limited periods of time only. Ideally, the maximum limits for equipment shall never be exceeded. When designing network infrastructure, these ratings need to be considered up-front to ensure suitable equipment is chosen, e.g. the correct size of cabling, sufficient transformation capacity and appropriate instrumentation.

To ensure a reliable electricity supply, voltage supply, voltage unbalance, voltage changes, voltage flicker, voltage dips and harmonic distortions should remain within the limits prescribed in NRS 048-2[20]. These standards are applicable to grid-based electricity supply, but it is recommended that similar standards are applied to off-grid systems to ensure compatibility in case it is connected to the grid in future. The integration of renewable energy plants across the HV/MV and LV levels would need to comply with the *Renewables Grid Code*[21].

Rapid changes in renewable energy generation output can cause flickers, specifically from solar- and wind-generated energy. The rapid changes are caused by fast changes in irradiance caused by moving clouds (in the case of PV panels), and rapid changes in wind speed (in the case of wind turbines).

N.4.4 LV network design considerations

The design of a LV network for a neighbourhood is based on the characteristics of the neighbourhood in terms of its layout and structure, and the various components such as roads, lighting, water, housing, open space etc. The available bulk sub-transmission as well as MV capacity should be factored in when doing the design. Other factors that need to be considered include the following:

- The best spatial layouts of MV/LV transformation capacity and LV feeder routing
- The choice of LV technology (three-phase, dual-phase or single-phase)
- Conductor sizing and configuration to supply the required ADMD within technical limits
- Large domestic demand that is not household demand (e.g. local retail, schools etc.). The LV design would need to ensure sufficient capacity for these larger consumers. The cost of the LV network is dependent on the load magnitudes, spatial density and any technology preferences (e.g. preference for buried cable).

A range of powerful tools is available to assist with LV network design. These tools help to create the most suitable designs and to select the most appropriate MV/LV technologies for the particular set of requirements. They are also useful in ensuring the system is cost effective, whilst maintaining statutory voltage drops across the designed network.

Voltage drop calculations are influenced by factors such as the diversity of consumers and unbalanced network loading. Network loading and capacity will change dynamically due to the following:

- Changes in weather
- Storms (high winds, lightning)
- Equipment failures (due to age / lack of maintenance)
- Existing/expected diurnal, monthly and seasonal variations in the demand profile of households and neighbourhoods

Voltage drop calculations

The Energy Research Data Portal of South Africa[22] provides access to valuable data, information and tools. It also makes available software developed as part of the Domestic Load Research Programme, namely the Eskom Distribution Pre-Electrification Tool (DPET) and the Distribution Profile Mixer (DPM).

The Distribution Pre-Electrification Tool is a software application that can be used to predict domestic consumer ADMD (with Herman Beta Parameters), consumption, and the load profile for a group of 60 or more consumers. The Herman Beta probabilistic method has been found to be more reliable than deterministic methods of calculating voltage drop in low voltage feeders. The calculation method is described in NRS 034-1[23].

The Distribution Profile Mixer Tool is a software application for estimating the aggregate hourly load profile for consumers from different domestic consumer classes. It can be used to analyse the total residential load on a feeder or in an area, and to model what-if scenarios for load planning.

LV feeder phase connections may have various configurations. Decisions need to be made regarding the number of phases to take from each node or pole as well as on how to arrange subsequent connections to minimise voltage drop. One of the largest contributing factors to voltage drop in LV networks is the presence of neutral currents due to unbalanced loading conditions. Not much can be done about the behaviour of consumers and technical imbalance minimisation techniques must be provided. Automated algorithms in software tools are available to assist with the calculations. Oscillating phase connection strategies are very effective in dealing with phase imbalances and should be incorporating when designing LV networks. Details of some of these strategies are provided in the *Distribution Network Planning Standard*[24].

N.4.5 Design considerations specific to microgrids

When designing a microgrid system, the following should be considered:

- Performance characteristics of energy resource supply options to be used by the microgrid
- Electrical service demand (existing type of load and future demand – future years)
- Number of customers/households

- The availability of land to construct the infrastructure
- Geological characteristics and planned land use developments
- Circuits' physical lengths
- Feeder configuration (networked/radial/looped)
- DC or AC microgrid configuration (or mixed)
- Desired reliability and power quality levels
- Voltage levels to be utilised
- Control and protection methods

According to IEC TS 62898-1[25], microgrids can primarily be connected in three ways, namely using a single bus structure, a multiple bus structure and a multilevel structure. An example of a multilevel structure is illustrated in Figure N.3.

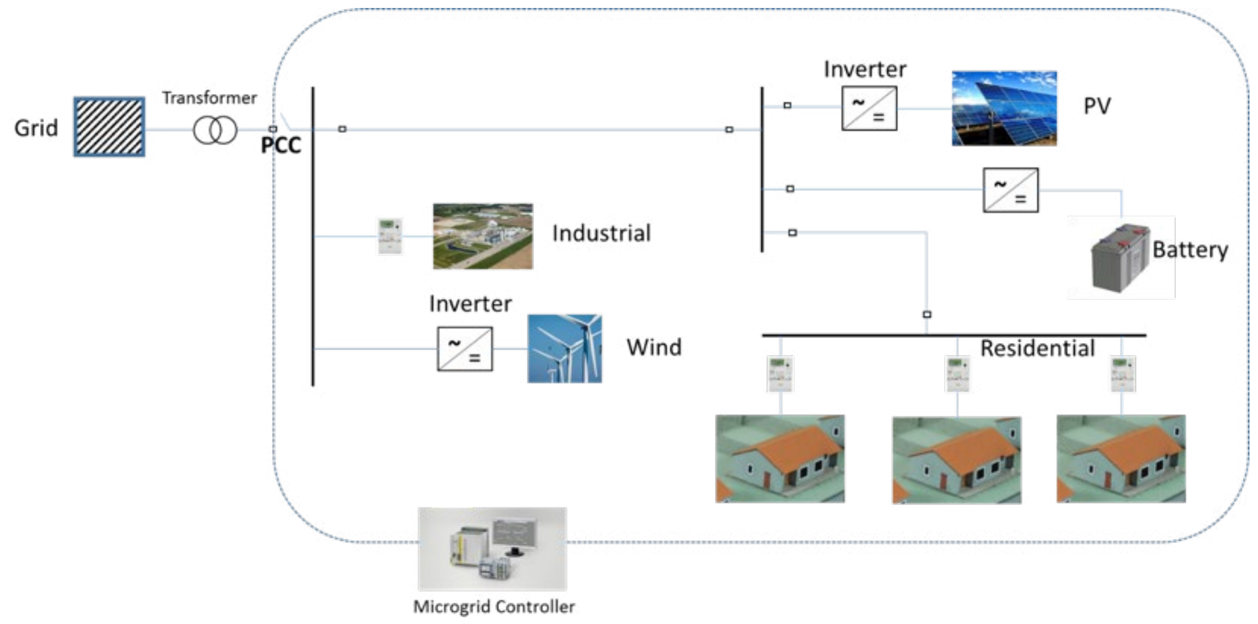

Figure N.3: Typical configuration of a microgrid

The microgrid controller unit should be able to provide energy and power balance of the microgrid in grid and off-grid modes. The controller must be able to communicate with all smart meters, protection relays and switching devices. The point of common coupling (PCC) indicated in Figure N.4 is responsible for switching between modes.

Studies may have to be conducted to ensure that possible challenges related to the integration of distributed generation and the microgrid are identified and effectively addressed. To ensure that the required standards are adhered to when designing a microgrid that will be connected to the grid, certain aspects need to be considered as outlined in IEEE Std 1547.7-2013[26], namely interconnection, equipment loading, unintentional islanding, protection design, coordination, fault rating, voltage regulation and reactive power management, power quality and communication. These aspects are briefly discussed next.

N.4.5.1 Microgrid interconnection

The connection of distributed generation resources requires a significant level of interaction control. Thus, designed microgrid controller units will be required to coordinate the operation of the main grid connection, and integrate renewables and non-renewable generation sources for a stable electrical power network. The microgrid controllable units should operate such that the switch between grid-connecter mode and island mode is made seamlessly. Frequency control, active power and voltage should be managed in both modes, as illustrated in Table N.2.

Table N.2: Characteristics of grid connected and island modes for microgrids

Connection mode	Characteristic
Grid connected	• The frequency control is supported by the grid. • Active power supply is balanced by the distributed resources and main grid. • Voltage and reactive power are managed by the main grid supply.
Island (off-grid)	• Frequency is maintained by the distributed generators. • The active power demand is met by the combination of distributed supply. • The reactive power is met by the distributed generation.

N.4.5.2 Equipment loading

In traditional grid connections, the electrical networks at the distribution level are designed for unidirectional power flow, and unidirectional short-circuit contribution, i.e. from the substation or primary source to the loads. However, in the case of microgrids, the distributed generators may change the power flow and appear to reduce loading. The loss of either the load or the distributed generator may cause equipment overloading. To avoid this, planning studies should be conducted.

N.4.5.3 Unintentional islanding

Network faults are likely to increase the number of unintended islanding in the network. Islanding can be controlled by sectionalising or disconnecting devices. There are many interrupting devices that can be designed to trip and clear a fault and automatically reconnect to restore load. However, an attempt to reconnect into the island unsynchronised with voltage, frequency, and/or phase angle can result in the damage of switchgear, power generation equipment and customer equipment. The unintentional island will also expose users to safety hazards as a result of energised disconnected conductors. This should be designed for in the microgrid to ensure a seamless and safe transition in the event of unintended islanding.

N.4.5.4 Protection design, coordination, and fault rating

Protection systems are designed to reduce the impact of faults that can be caused by lightning or problems in the electrical system. Distributed generation systems need to be coordinated with the protection systems employed on distribution networks. The addition of SSEG to distribution circuits will affect coordination. Protection settings can be oversensitised or desensitised by distributed generation fault current contributions, depending on the location of the existing protective device. Connecting distributed generation resources to a distribution feeder can introduce sources of short-circuit current contribution to the distribution system. This could result in increased short-circuit currents, potentially reaching damaging levels and resulting in protection desensitisation and a potential breach of protection coordination. Information and guidance on the protection of distribution systems are provided in NRS 034-1[27].

N.4.5.5 Voltage regulation and reactive power management

Generation in the distribution system must maintain the voltage limits during operations. The system has to be designed to avoid causing interference with the normal operation of the voltage regulation equipment. Where generation is variable in nature, the resultant voltage fluctuation may cause adverse effects on voltage regulation equipment. Voltage regulator controls may need to be modified or replaced when power is injected from the load side of the device. Furthermore, reactive power exchange at the point of common coupling has an impact on voltage regulation. Distributed generation output changes may occur more rapidly for circuit voltage controls, in which case voltage fluctuations of approximately one minute or less can occur.

N.4.5.6 Communications for Microgrids

When multiple generation, energy storage and load control devices are interconnected to form a microgrid, communication coordination is essential. Microgrid operation and fast recovery will significantly benefit from various communication-based control, protection and automation techniques.

Glossary, acronyms, abbreviations

Glossary

After Diversity Maximum Demand (ADMD)
The simultaneous maximum demand of a group of homogeneous consumers divided by the number of consumers, normally expressed in kVA. Thus, the ADMD of N consumers is:

$$\text{ADMD (N)} = \frac{\text{MD(N)}}{\text{N}}$$

This value generally decreases to an approximately constant value for 1 000 or more consumers and has therefore been chosen as a convenient reference value. NOTE: Practically no difference in ADMD exists between 100 and 1 000 consumers.

ADMD with no mention of the number of consumers (N) is defined as that representing the ADMD of 1 000 consumers:

ADMD = ADMD(1 000)

For customers who have the potential to have a high or very high demand, an individual customer's maximum demand is generally approximately two to three times the ADMD for a group of similar customers. For customers with a limited potential demand, in the very low, low, or moderate consumption range, an individual customer's consumption is typically four to five times the ADMD for a group of similar customers.

Low Voltage (LV)
The range of AC voltages up to and including 1 000 V r.m.s. (see SABS 1019:1985 for a full definition).

Living Standards Measure (LSM)
LSM levels have been developed by the South African Audience Research Foundation (SAARF) as part of the all media and product survey (AMPS) as a market segmentation tool. It segments households based on a range of appliances owned by the household. Households are categorised into 14 discrete levels making up LSM levels 1-10 (sub-ranges exist in LSM levels 7-10).

Maximum Demand
The highest averaged electrical demand for a specified period. (Typically, 5 to 60 min and 30 min are normally used, as these are close to the thermal constant of transformers and lines).

Medium voltage
The range of AC voltages exceeding low voltage, up to and including 44 kV. (See SABS 1019:1985 for a full definition).

Acronyms and abbreviations

ADMD	After Diversity Maximum Demand
COUE	Cost of Unserved Energy
CSP	Concentrated Solar Power
DSR	Demand side response
HD	High-density
kW	Kilowatt
kVA	Kilovolt-ampere
LD	Low-density
LSM	Living Standards Measure
LV	Low voltage
MV	Medium voltage
SAIDI	System Average Interruption Duration Index
SSEG	Small-scale embedded generation

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Section O

Cross-cutting issues

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 O
Cross-cutting issues

The Neighbourhood Planning and Design Guide

Table of contents

O.1 Planning and designing safe communities

O.1.1 Crime and the physical environment

The physical (built) environment is often an important factor that contributes to the likelihood (or not) of a crime occurring in a particular location. Changing the physical environment could therefore either create challenges for certain types of crime to be committed or reduce incidents of crime and violence in a particular area. Crime Prevention through Environmental Design is a well-recognised and widely practised approach to crime prevention that is internationally most commonly known by its acronym, CPTED (pronounced sep-ted).

A definition of CPTED

CPTED is a multi-disciplinary approach to deterring criminal behaviour through environmental design. CPTED strategies rely upon the ability to influence offender decisions that precede criminal acts by affecting the built, social and administrative environment.

The International CPTED Association (ICA)[1]

O.1.2 CPTED in South Africa

O.1.2.1 Background

It is widely acknowledged that certain opportunities for criminal events to occur could be reduced by applying sound planning, design and management principles to the built environment. It is also accepted that the physical environment could play a significant role in influencing perceptions of safety.

In South Africa, the important role of planning, design and management in creating safe human settlements is acknowledged in the National Development Plan (NDP)[2] and the Integrated Urban Development Framework (IUDF).[3] Furthermore, the White Paper on Safety and Security[4] published in 2016 recognises "Safety through environmental design" as one of the six themes that inform crime and violence prevention.

O.1.2.2 The South African context

South Africa's particular spatial and socio-economic characteristics and the country's history of forced segregation have resulted in a distinct relationship between crime and the physical environment. Spatial patterns and the form and structure of South African cities and towns are the result of planning principles and approaches that were largely influenced by the country's apartheid ideology. The poorest communities are, for the most part, located on the urban periphery. This means that residents have to travel long distances, not only to and from their places of employment, but also to reach commercial, social, recreational, healthcare and other facilities. These neighbourhoods often lack adequate infrastructure (e.g. electricity, water, sanitation), recreational facilities and amenities (e.g. community halls and sports facilities), as well as safe public spaces (e.g. parks).

The conditions described above often encourage crime and result in environments where people feel unsafe. Factors such as the lack of adequate lighting in public spaces (especially streets), the absence of street names and house numbers, and the presence of informal (and often illegal) taverns further contribute to the creation of unsafe conditions. It is often difficult for the police to patrol or respond to calls in these areas due to the poor condition of streets or – in the case of informal settlements – the complete lack of vehicle access routes. Also, even though a large proportion of the South African population does not own a motor vehicle, most neighbourhoods have not been designed to accommodate pedestrians and cyclists, and public transport is not always effective, efficient, safe, reliable and affordable. People are especially vulnerable to crime and violence when they have to travel.

While poorer communities do not have access to basic security measures, more affluent residents have the resources to implement a whole range of such measures. In addition to alarm systems and armed response services, gated communities are becoming increasingly popular. These gated communities can take on various forms, including large security (lifestyle) estates, smaller security complexes, or enclosed neighbourhoods (road closures) where existing public streets are closed or boomed off.

The significant differences between the social and spatial contexts of different South African communities and neighbourhoods place a complex set of demands on crime prevention initiatives. Fortunately, CPTED interventions can often be implemented effectively in any of these contexts and can form part of a crime prevention strategy that suits the needs of any community.[5]

O.1.3 CPTED principles for South Africa

A number of principles guide the implementation of CPTED. These vary slightly between countries, depending on local interpretations. Five principles that were developed for the South African context are outlined in *Designing Safer Places - A Manual for Crime Prevention through Planning and Design.*[6] They provide guidance when decisions need to be made regarding the planning and design of the physical environment with safety and security in mind. These principles can be regarded as objectives to be achieved when developing or redeveloping spaces, and they relate to the following:

- Surveillance and visibility
- Territoriality
- Access and escape routes
- Image and aesthetics
- Target hardening

A more detailed description of each principle is provided below. More information is also available on the SaferSpaces website.[7]

Surveillance and visibility

Objective: Optimise visibility and maximise opportunities for observance of public and private areas by users or residents during the course of their normal activities (passive surveillance) and/or by police or other security personnel (active surveillance).

Factors that could play a role include uninterrupted lines of sight; levels and types of lighting; positioning and nature of windows, doors and other openings; building layout and the distances between buildings; the size of the public spaces; and the extent, degree and type of use of such spaces.

Figure O.1.1: The glass lobby increases visibility and the CCTV camera provides additional surveillance

Figure O.1.2: Mixed activities, layout and the positioning of facilities and windows improve surveillance

Passive surveillance is often referred to as the presence of 'protective eyes' or 'eyes on the street'. The extent of visual contact that people have with a space, together with the degree of their being visible to others, determines the extent to which they can intervene and whether the users feel safe. The zoning of areas of the city and the functionality of buildings are key elements in determining whether protective eyes are present day and night, or not.

Surveillance is improved if there is good visibility. Dark streets, alleys, entrances and doorways can act as havens for potential offenders and increase residents' and visitors' fear of crime. The way in which lighting is designed and positioned, and the way roads and paths are laid out, can obviate many of these problems and ensure that both the physical environments and the users are visible to others using the environment.

Territoriality

Objective: Encourage a sense of ownership of and responsibility for a space by employing mechanisms that will allow residents or users to identify with the space and experience it as legible.

A sense of ownership and responsibility for a particular environment improves the likelihood of passive observers intervening. Places should be designed and managed in ways that encourage owners/users to take responsibility for them and feel responsible for their use, upkeep and maintenance.

Figure O.1.3: Residents taking ownership of a public area in front of their house

Figure O.1.4: Plants are used to define public and semi-public spaces

Photo credit: Alexandra Renewal Project (L)

Public, semi-public and private spaces should be well defined, for instance through the use of fences, differences in levels, vegetation and landscaping, surface treatment (e.g. different types of paving), bollards, etc.

Access and escape routes

Objective: Limit opportunities for offenders to utilise access and escape routes such as vacant land, and enhance the level of ease with which potential victims could find and access escape routes.

Figure O.1.5: This green belt provides easy access and escape routes for offenders

Figure O.1.6: Once someone has entered this subway, opportunities to escape an offender are limited

Clear signposting of streets, buildings and exit routes are important ways of assisting potential victims. The design of elements such as subways also needs to be considered carefully to reduce perceptions that one will not be able to escape from an offender.

Image and aesthetics

Objective: Ensure that the physical appearance of an environment creates a positive image and instils feelings of safety in users.

The image of spaces and facilities can be improved by ensuring human scale in design, using attractive colours and/or materials and providing adequate lighting. Effective maintenance of the physical environment and infrastructure is a critical aspect of this principle.

Photo credits: Alexandra Renewal Project

Figure O.1.7: This unkempt area does not create the impression of it being a safe neighbourhood

Figure O.1.8: This clean area creates a positive image of the neighbourhood

Urban decay and its resultant degradation cause people who use these areas to feel unsafe. Often this reduces the number of users, which could further exacerbate the crime problem. The good design and the effective management of public spaces are necessary to prevent them from becoming actual or perceived 'hot spots' for crime. Vacant land that is not maintained, unoccupied buildings, as well as litter and the breakdown of services contribute to urban decay.

Target hardening

Objective: Reduce the attractiveness or vulnerability of potential targets by physically strengthening them and/or installing mechanisms that will increase the effort required to commit an offence.

Target hardening measures are often the first to be considered in response to real criminal events or perceived threats. Perimeter walls or fences, security gates, burglar bars and alarm systems are all mechanisms used to implement this principle.

Figure O.1.9: A fence provides opportunities for surveillance onto and from the street

Figure O.1.10: High walls reduce opportunities for surveillance

Care should be taken to ensure that other principles are not compromised when implementing target-hardening interventions. For instance, a solid high wall around a property (target hardening) violates the principle of surveillance and visibility.

O.1.4 Applying the principles

Employing these principles in combination may well reduce crime. However, none of the principles should be viewed in isolation and the context within which they are to be applied should be taken into account. When applying any one of the principles, the implications for any of the others must always be considered.

The importance of maintenance

A lack of maintenance of the physical environment and infrastructure could create opportunities for crime and be part of the reason why people do not feel safe in certain areas. For instance, if lighting has been provided to reduce crime in a park or along a pedestrian route, a lack of maintenance that results in the lights not working would mean that the intervention has no real effect.

A well-maintained environment can contribute to people developing a sense of pride in their neighbourhood and encourage them to take responsibility for it. This promotes a key CPTED objective, namely to encourage citizens to take ownership of their neighbourhoods.

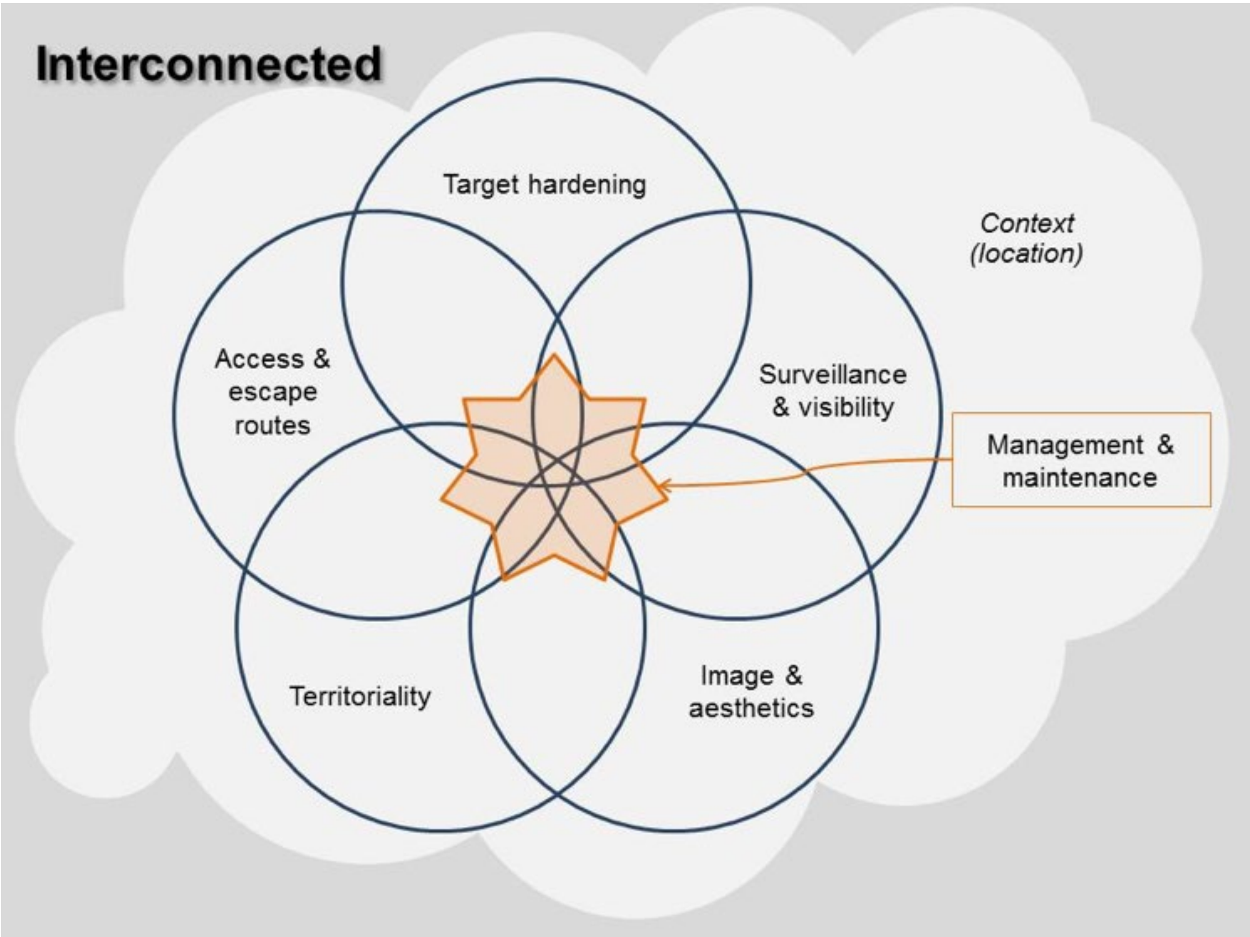

Figure O.1.11: CPTED principles, context, and management and maintenance

O.1.5 Implementing CPTED in South Africa

CPTED could play an important role in improving the sustainability of South African cities and towns.[8] CPTED initiatives would not only reduce crime in specific local places (micro-level), they could also contribute to the transformation of society in general through changes to the urban form (macro-level). Such macro-level interventions could be aimed at addressing certain spatial characteristics and associated problems, including the following:

- The spatial dislocation of the poor, which results in long and costly commuting patterns and exposes commuters to victimisation.
- The separation of communities by vacant land (buffer strips used in the past to divide people), which provides many opportunities for criminal activity.
- The rigid mono-functional zoning of land, which leaves some areas deserted at night and others deserted during the day, thus increasing opportunities for crime.
- The effective exclusion of many city residents from the amenities and economic opportunities offered by the city.

In order to address these challenges effectively, CPTED needs to be implemented at the following levels:

- *Planning level* – physical urban planning approaches at strategic level, such as strategies to promote the reduction of vacant land, to encourage mixed land use and to support the integration of communities.
- *Design level* – detailed design of different urban elements, such as the transport system, roads, public open spaces, buildings and the spaces between them.
- *Management level* – managing the entire urban system and the precincts within it (e.g. infrastructure, maintenance and by-law enforcement), as well as managing and facilitating the implementation of CPTED initiatives.

O.1.6 Implementing CPTED in South Africa

CPTED could play a key role in reducing crime and creating safer communities. However, it should be remembered that CPTED interventions can only address specific types of crime in particular locations. Also, crime prevention measures that have worked in a particular situation may not be as effective under different conditions. It is therefore essential to develop responses to crime problems based on a thorough understanding of the local context, including the crime situation and the characteristics of the physical, social and institutional environments.

CPTED should ideally form part of a broader, integrated crime prevention initiative that involves other approaches, including law enforcement and social crime prevention initiatives. A community-based crime prevention strategy could assist in coordinating such interventions. The process to develop a local crime prevention strategy is described in *Making South Africa Safe – A Manual for Community-based Crime Prevention.*[9]

Figure O.1.12: CPTED interventions should be context specific and form part of broader crime prevention initiatives

O.2 Universal design

O.2.1 The concept of universal design

Neighbourhoods should, as far as possible, be accessible to all people, and everybody should be able to use and move between buildings, public open spaces and amenities safely and free from constraints. Therefore, special care has to be taken when structuring a neighbourhood and planning and designing its different components such as streets, pathways, parks, squares, and social facilities. To create universally accessible neighbourhoods, it is important to consider the principles of universal design outlined in this Section in conjunction with the guidance provided in Sections F to N of this Guide.

The universal design approach aims to support the development of neighbourhoods that meet the needs of the widest possible range of users regardless of age, height, weight and shape, and including people with illnesses or disabilities (temporary or permanent) that affect aspects such as their mobility, balance, sight, hearing, touch, memory, strength, stamina etc. It is clear that neighbourhoods developed in accordance with the principles of universal design will benefit all people and result in an environment that can be enjoyed by everyone.

Universal design is described by the Centre for Excellence in Universal Design as "...the design and composition of an environment so that it may be accessed, understood and used, to the greatest possible extent, by people of any age or size, regardless of any physical, sensory, mental health or intellectual ability or disability, in the most independent and natural manner possible".[10]

Universal design and universal access

The White Paper on the Rights of Persons with Disabilities, 2015[11] defines the concepts of universal design and universal access as follows:

"Universal access means the removal of cultural, physical, social and other barriers that prevent people with disabilities from entering, using or benefiting from the various systems of society that are available to other citizens and residents. The absence of accessibility or the denial of access is the loss of opportunities to take part in the community on an equal basis with others."

"Universal design is the design of products, environments, programmes and services to be usable by all persons to the greatest extent possible without the need for adaptation or specialised design. Assistive devices and technologies for particular groups of persons with disabilities where these are needed, must also respond to the principles of universal design. Universal design is therefore the most important tool to achieve universal access."

O.2.2 The principles of universal design

The following seven universal design principles, developed by the Centre for Universal Design[12], provide useful guidance when planning and designing neighbourhoods:

- Equitable use
- Flexibility in use
- Simple and intuitive use
- Perceptible information
- Tolerance for error
- Low physical effort
- Size and space for approach and use

The descriptions of the principles provided below were developed by the Centre for Universal Design and are reproduced without any alterations as required by the authors[13].

(i) Equitable use

Definition
The design is useful and marketable to people with diverse abilities.

Guidelines
- Provide the same means of use for all users: identical whenever possible; equivalent when not.
- Avoid segregating or stigmatising any users.
- Provisions for privacy, security, and safety should be equally available to all users.
- Make the design appealing to all users.

(ii) Flexibility in use

Definition
The design accommodates a wide range of individual preferences and abilities.

Guidelines
- Provide choice in methods of use.
- Accommodate right- or left-handed access and use.
- Facilitate the user's accuracy and precision.
- Provide adaptability to the user's pace.

(iii) Simple and intuitive use

Definition
The use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

Guidelines
- Eliminate unnecessary complexity.
- Be consistent with user expectations and intuition.

- Accommodate a wide range of literacy and language skills.
- Arrange information consistent with its importance.
- Provide effective prompting and feedback during and after task completion.

(iv) Perceptible information

Definition
The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Guidelines
- Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.
- Provide adequate contrast between essential information and its surroundings.
- Maximise "legibility" of essential information.
- Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).
- Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

(v) Tolerance for error

Definition
The design minimises hazards and the adverse consequences of accidental or unintended actions.

Guidelines
- Arrange elements to minimise hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
- Provide warnings of hazards and errors.
- Provide fail safe features.
- Discourage unconscious action in tasks that require vigilance.

(vi) Low physical effort

Definition
The design can be used efficiently, comfortably, and with a minimum of fatigue.

Guidelines
- Allow user to maintain a neutral body position.
- Use reasonable operating forces.
- Minimise repetitive actions.
- Minimise sustained physical effort.

(vii) Size and space for approach and use

Definition
Appropriate size and space is provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility.

Guidelines

- Provide a clear line of sight to important elements for any seated or standing user.
- Make reach to all components comfortable for any seated or standing user.
- Accommodate variations in hand and grip size.
- Provide adequate space for the use of assistive devices or personal assistance.

O.2.3 Applying the principles of universal design

The application of the principles of universal design should be based on a thorough understanding of the nature of the development, the features of the physical environment where the site is located, and the community that will be served. The principles provide a sound basis for making design decisions, but the decisions also have to be guided by local conditions, legislation, standards and regulations.[14]

O.2.3.1 The regulatory environment

A range of legislation, policies and strategies promote and prioritise the rights of persons with disabilities. A number of standards have also been issued to guide different design aspects in the built environment. Since they are not discussed in detail, it is vital to consult the relevant documents before commencing with the planning and design of a neighbourhood project.

The United Nations Convention on the Rights of Persons with Disabilities (UNCRPD)[15] was adopted in 2006 and South Africa is one of the signatories of the convention. The 2015 White Paper on the Rights of Persons with Disabilities (WPRPD) is the national response to the UNCRPD, explaining how the convention will be implemented in South Africa.

The White Paper on the Rights of Persons with Disabilities, 2015 is based on the 'social model to addressing disability'. According to the White Paper, the social model focuses on the abilities of persons with disabilities rather than their differences, fosters respect for inability and recognises persons with disabilities as equal citizens with full political, social, economic and human rights.

The White Paper states that the social model does not locate the "problem" within the person with impairment, but it emphasises that barriers in the environment disable the person with the impairment. The model is aimed at inclusion rather than exclusion of persons with disabilities from mainstream life.

Legislation that provide for the protection and promotion of the rights of persons with disabilities include a range of acts, of which the Promotion of Equality and Prevention of Unfair Discrimination Act (2000) is the most prominent. The act specifically determines that no person may unfairly discriminate against any person on the grounds of disability by

- denying or removing from any person who has a disability, any supporting or enabling facility necessary for their functioning in society,
- contravening the code of practice or regulations of the South African Bureau of Standards that govern environmental accessibility, and
- failing to eliminate obstacles that unfairly limit or restrict persons with disabilities from enjoying equal opportunities or failing to take steps to reasonably accommodate the needs of such persons[16].

Various standards and regulations are relevant to universal design, including the following:

- SANS 10400-S
  The application of the National Building Regulations Part S: Facilities for persons with disabilities. The regulations apply to public buildings and housing, and they include regulations regarding external pathways to buildings, ramps, disabled toilets, accessible routes and doorways, and signage. These regulations should always be considered in conjunction with the information provided in this Guide.
- SANS 784: 2008
  Design for access and mobility - tactile indicators
- SANS 1545-4: 2015
  Safety rules for the construction and installation of lifts Part 4: Lifts for persons with disabilities (vertical lifting platforms)
- SANS 22411: 2009
  Information technology – survey of icons and symbols that provide access to functions and facilities to improve the use of information technology products by the elderly and persons with disabilities
- ISO 21542: 2011
  Building Construction – Accessibility and Usability of the Built Environment
- ISO 23600: 2007
  Assistive products for persons with vision impairments and persons with vision and hearing impairments - Acoustic and tactile signals for pedestrian traffic lights

National Technical Requirements - NTR 1 and NTR 2

The Department of Transport has developed technical standards on the application of universal design principles and SANS 10400 Part S in relation to public transport and the design of public spaces. These documents are known as the National Technical Requirements (NTR), and they deal with the following:

NTR1: Pedestrian crossings[17]
NTR2: Public transport vehicles and stops[18]

These two documents provide useful information and should be consulted when applying this Guide.

O.2.3.2 Incorporating universal design into the neighbourhood development process

The process of developing a neighbourhood should be guided by the principles of universal design from the very start. These principles should be considered even when decisions are made during the planning phase of the project, and they should be integrated into the design of a neighbourhood from the outset. Universal design should not be regarded as a luxury, or as a few elements that can be added after the design has been completed. It could be very expensive to introduce changes at a late stage of the design process. Attempts to retro fit certain components to accommodate people with disabilities may be difficult and may not have the required result (see Figure O.2.1).


Figure O.2.1: If universal design principles are implemented as an afterthought they do not have the required results

Neighbourhood planning and design decisions need to be informed by a careful assessment of context and place. Characteristics such as the topography and natural features of the development site, existing infrastructure (e.g. streets, pathways and public open spaces) and the profile and composition of the potential residents have to be taken into account. However, when developing a new neighbourhood, it should not be assumed that there is no need for it to be accessible to all purely based on the current characteristics of the expected residents. For instance, there may not be people with disabilities, and elderly residents may not be expected to live in the community, but it does not mean that they will not visit the neighbourhood, or move in over time. It would therefore be useful to consult with a range of potential users to identify the most appropriate way of including universal design options in the neighbourhood.

According to the Commission for Architecture and the Built Environment[19] good design is inclusive:

"Good design should reflect the diversity of people who use it and not impose barriers of any kind. By designing and managing the environment inclusively, the frustration and hardship experienced by many – including disabled people, older people and families with small children – can be overcome. We all benefit from an environment designed in line with inclusive principles."

When applying the principles of universal design in practice, various factors need to be considered when making decisions regarding the design of public spaces such as sidewalks, pathways, squares, parks, and the open areas between buildings. Some of the factors are briefly outlined below. More information regarding these and other aspects that have to be considered is available in SANS 10400 Part S, NTR1, NTR2 and the *Non-Motorised Transport (NMT) Facility Guidelines* developed by the Department of Transport.[20]

(i) Wayfinding

Various mechanisms can be employed to make it relatively easy for everyone, including people with disabilities, to find their way around a neighbourhood. Tactile, visual and audio cues can be provided in a number of ways.

Tactile ground surface indicators (TGSIs), often referred to as tactile paving, could be very useful in assisting visually impaired people with wayfinding. It is used to provide guidance or to warn of potential hazards, for instance a change in level, or a pedestrian crossing. Different textures have particular meanings that convey specific information; therefore it is important to use the appropriate surface pattern (e.g. blister or corduroy) in the correct location and manner (layout) as specified in SANS 784: 2008 (Design for access and mobility - tactile indicators). More information regarding the use of TGSIs at pedestrian crossings is available in NTR1.

Photo credit: Department of Transport

Figure O.1.2: Tactile paving used at a bus stop (L) and at a pedestrian crossing (R)

Audible signals assist visually impaired people by providing them with information that allows them to cross a street safely at a pedestrian crossing. Signage that provides information to assist people with wayfinding should include braille symbols at a level where people in wheelchairs can reach it.

(ii) Pedestrian crossings

Everyone is vulnerable when crossing a street, but people with disabilities (in particular people who are deaf, hard of hearing, visually impaired or those with walking difficulties) are especially vulnerable. It is therefore critical that pedestrian crossings should be carefully designed in accordance with the specifications provided in NTR 1. Aspects to consider include the number of lines that can safely be crossed before a safe resting place is reached, kerb radii suitable for a particular intersection crossing and the siting of traffic light poles at crossings.

(iii) Pathways free of obstacles

Sidewalks, pathways and NMT routes through public open spaces should be free of obstacles, trip hazards and protrusions such as exposed tree roots, outward opening windows and doors, and street furniture (signage, public seating, lighting, bollards etc.). Specific attention should be paid to the placement of street furniture to ensure that an obvious line of travel is maintained. Certain elements such as benches, lighting, signage and dust bins should be grouped or positioned in a coordinated way in order to create a clear pathway that is easy to follow.

The design and placement of bollards should be carefully considered. They should be clearly visible and should never be linked with ropes or chains. Bollards should be positioned in such a way that they do not present a hazard or obstruction for wheelchair users, people pushing prams, visually impaired people, etc.

Special attention should be paid to the design of a stormwater drainage system that will ensure that water is effectively cleared from walkways, sidewalks, pedestrian crossings etc. (see **Section L**) Puddles of water present a hazard to pedestrians, cyclists, wheelchair users, people with walking difficulties, visually impaired people etc. Decisions regarding the gradient and surface levels required to accommodate stormwater drainage should be reconciled with the gradient specifications for ramps, pathways and pedestrian crossings provided in NTR and SANS 10400 Part S.

Manhole covers and access points to other underground services should not be placed in pathways, sidewalks or at pedestrian crossings. They present trip hazards and create obstacles that reduce the effective width available to users of the walkway, sidewalk etc. If their covers are removed (or stolen), it presents a very dangerous situation.

Figure O.2.3: Street furniture should be carefully positioned to maintain a clear pathway

(iv) Surface materials

The material used on horizontal surfaces should be chosen wisely to ensure that it is appropriate for the context and does not create a hazard or inconvenience some users. Pathway surfaces should be smooth but not slippery. Many people find uneven surfaces such as loose gravel or cobblestone paving uncomfortable. Some people, for instance the elderly, people with walking difficulties, wheelchair users and people with prams or wheeled luggage find it difficult, and even dangerous, to negotiate these types of surfaces.

Photo credit: Louis Smit (L) and Humphrey Muleba (R) on Unsplash

Figure O.2.4: Pathways and sidewalks with level, even and slip-resistant surfaces will benefit all users

If a pathway is on the same level as the area directly adjacent to it and the surfaces are flush, it is advisable to use different surface materials to demarcate the pathway and define its edge. By using different surface treatments, it will be easier for people, especially those who are visually impaired, to distinguish between the pathway and the adjacent area, e.g. a street with motor vehicles, or outdoor seating for a restaurant. The intention is to prevent people from wandering off the walkway causing them to get lost, or leading them into an area that may present hazards and obstacles. Care should be taken when introducing level differences or using raised kerbs to delineate a pathway, since it may be helpful to some but present a tripping hazard to others.

Photo credit: Chris Barbalis on Unsplash

Figure O.2.5: Use different surface materials to demarcate a pathway and define its edge

Balancing different needs

In certain cases, a particular universal design option may be appropriate for some people but not for others. For instance, design elements such as raised kerbs may be useful to visually impaired people because they define the edge of a pathway or pavement. However, raised kerbs could inconvenience, or even be hazardous to others such as wheelchair users and people with walking difficulties. Well-designed dropped kerbs would therefore be required in carefully identified locations, taking into consideration the needs of all users.

(v) Ramps

In addition to steps, ramps should be provided where there is a change in level. Ramp gradients and the provision of landings should meet the specifications provided in SANS 10400 Part S. The positioning and design of ramps should be carefully considered to ensure that they are not too steep for people with wheelchairs and walking difficulties.

Figure O.2.6: Both stairs and ramps should be provided (L) and ramps should have landings at convenient intervals (R)

(vi) Pathways and sidewalks that can accommodate all users

Universal design supports the idea that most destinations in a neighbourhood should be reachable by walking, cycling and using public transport. Many people with disabilities find it difficult to walk long distances and walkable neighbourhoods have a number of benefits to all users and residents. See Section F.4.2 for a discussion of walkable neighbourhoods.

Pedestrian routes should be continuous throughout a neighbourhood. This means that pathways and sidewalks should not be provided arbitrarily but they should be linked to provide an uninterrupted route to and from different destinations. Sidewalks with deliberate barriers or sidewalks that are taken over by restaurants force pedestrians to either use the roadway (which has safety implications) or select an alternative route (which can be inconvenient and time-consuming). Unnecessary fences and gates (often part of gated communities or security complexes) can also result in unnecessary long travel distances.

Photo credit: Department of Transport (L); Robert Ruggerio on Unsplash (R)

Figure O.2.7: A bus stop (L) and parking spaces (R) that can accommodate wheelchair users

O.2.4 Management and maintenance

Once an environment has been designed according to universal design principles, it is essential that the environment is managed and the infrastructure maintained. If an effective management and maintenance regime is not implemented, the environment may lose the features that were incorporated to assist people with disabilities. For instance, if cracked floor tiles or broken paving blocks are not replaced, they are not fit for purpose anymore and become hazards. Similarly, if street furniture components are added randomly, they may obstruct pathways and cause hazards. Therefore, universal access is the result of an ongoing process, not of a once-off design intervention.

Glossary, acronyms, abbreviations

Glossary

CPTED

According to the International CPTED Association, CPTED is a multi-disciplinary approach to deterring criminal behaviour through environmental design. CPTED strategies rely upon the ability to influence offender decisions that precede criminal acts by affecting the built, social and administrative environment.

Universal design

According to the White Paper on the Rights of Persons with Disabilities, universal design is the design of products, environments, programmes and services to be usable by all persons to the greatest extent possible without the need for adaptation or specialised design. Assistive devices and technologies for particular groups of persons with disabilities where these are needed, must also respond to the principles of universal design. Universal design is therefore the most important tool to achieve universal access.

Acronyms and abbreviations

CPTED	Crime Prevention through Environmental Design
SANS	South African National Standard
TGSI	Tactile Guidance Surface Indicators

Endnotes

1 The International CPTED Association (ICA) is an international organisation aimed at promoting the creation of safer environments and at improving the quality of life through the use of CPTED principles and strategies. http://www.cpted.net

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12 The Center for Universal Design. 1997. *The Principles of Universal Design, Version 2.0.* Raleigh, NC: North Carolina State University. https://projects.ncsu.edu/design/cud/about_ud/udprinciples.htm
Compiled by advocates of universal design, listed in alphabetical order: Bettye Rose Connell, Mike Jones, Ron Mace, Jim Mueller, Abir Mullick, Elaine Ostroff, Jon Sanford, Ed Steinfeld, Molly Story, and Gregg Vanderheiden.

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14 The Principles of Universal Design were conceived and developed by The Center for Universal Design at North Carolina State University. Use or application of the Principles in any form by an individual or organisation is separate and distinct from the Principles and does not constitute or imply acceptance or endorsement by The Center for Universal Design of the use or application.

15 United Nations Convention on the Rights of Persons with Disabilities (UNCRPD)
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human settlements

Department:
Human Settlements
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