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Compiled by	Approved by	Authorised by
S. Ramsamy/ M. J. van Heerden	F. Grootboom	G. Macintosh
Engineer	Chief Engineer	Manager (Acting)
Dams, Waterways and Hydro Engineering CoE	Dams, Waterways and Hydro Engineering CoE	Dams, Waterways and Hydro Engineering CoE
Date: 12/03/2018	Date: 12/03/2018	Date: 12/03/2018

Supported by SCOT CTC

G. Dudenska
SCOT Civil TC Chairperson

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1. INTRODUCTION

This procedure deals with the design of drainage and sewerage infrastructure.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

The Drainage and Sewerage standard presents clear and concise technical requirements, policies, and processes to enable design professionals to prepare designs and specifications necessary for development of drainage and sewerage projects within Eskom. This document is not to be considered complete nor is it a substitute for the requirements of the Drainage and Sewerage Codes, or other applicable laws. Should any conflicts arise between the information contained herein and the Drainage and Sewerage Codes, the information contained within the Drainage and Sanitation Codes shall govern.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems.

[2] 240-53113685: Design Review Procedure

[3] 240-53114002: Engineering Change Procedure

[4] 240-48929482: Tender Evaluation Procedure

[5] 240-43327398: Engineering Policy

[6] 240-77569976: Eskom Climate Change Policy

2.2.2 Informative

[1] SANS 1200 – Standards

[2] SANS 791 - Unplasticised poly(vinyl chloride) (PVC-U) sewer and drain pipes and pipe fittings

[3] SANS 677 - Concrete non-pressure pipes

[4] SANRAL Drainage Manual (2013). Pretoria; South Africa National Road Agency Ltd

[5] HRU (1979). Design Flood Determination in South Africa. Hydrological Research Unit, Department of Civil Engineering, University of Witwatersrand, RSA

[6] Chadwick, Andrew, John Morfett, and Martin Borthwick (2004). Hydraulics in Civil and Environmental Engineering. London: Spon

[7] Design and Construction of Sanitary and Storm Sewer. ASCE Manual

[8] John S Scott, A Dictionary of Civil Engineering. Penguin Reference Books

[9] TR102, P T Adamson, Southern African storm rainfall, DWA, 1981

[10] Johan Koekemoer, Introduction to Sewer Design, Candidate Academy, 2011

[11] Haested Methods, Computer Applications in Hydraulic Engineering, 7th Ed, Bentley, 2007

[12] SANS 347: Categorization and conformity assessment criteria for all pressure equipment

[13] Occupational, Health and Safety Act, Act 85 of 1993;

[14] SANS 10400 – Building Code

[15] GGSS 0690 – Specification for Medium Pressure Pipelines (Rev 0)

[16] SSZ45-17 – Corrosion Protection Specification of Medupi Power Station (Rev 2)

[17] GGSS 0423 – Specification for Low Pressure Valves (Rev 2)

[18] 474-10613 – PVC piping versus HDPE piping- Kusile Power Station Lessons Learnt

[19] AWWA M11 – Steel Water Pipe: A Guide for Design and Installation (M11), Fourth Edition

[20] The South African Guidelines for Sustainable Drainage Systems, WRC Report No. TT 558/13, 2013

2.3 DEFINITIONS

Definition	Description
Catchment	A geographical area draining to a sewer or receiving water
CCTV	Closed circuit television used to carry out internal inspection and survey of pipelines
Closed-Circuit Television Inspection (CCTV)	Inspection method utilizing a closed circuit television camera system with appropriate transport and lighting mechanisms to view the interior surface of sewer pipes and structures
Cured-in-place pipe (CIPP)	Cured In Place Pipe; a rehabilitation technique whereby a flexible resin-impregnated tube is installed into an existing pipe and then cured to a hard finish, usually assuming the shape of the existing pipe. A lining system in which a thin flexible tube of polymer or glass fibre fabric is impregnated with thermoset resin and expanded by means of fluid pressure into position on the inner wall of a defective pipeline before curing the resin to harden the material. The uncured material may be installed by winch or inverted by water or air pressure, with or without the aid of a turning belt.
Collector Sewer	A sewer to which one or more sewer connections are tributary
Collection System	A network of sewers which serves one or more catchment areas
Compaction	The densification of a soil by means of mechanical manipulation
Contract Documents	Documents prepared by the owner and project engineer for bidding and for awarding a project; can include bid forms, general conditions, special conditions, technical specifications, drawings, geotechnical data reports, and geotechnical baseline reports
Cover	Distance from the outside top of the pipe to the final grade of the ground surface
Culvert	A covered channel or pipe for carrying stormwater below ground level, usually under a road or railway.
Design Specification	Establishes specific requirements the contractor must use, including means and methods. A design specification creates an implied warranty that if the contractor uses the specified means and methods along with industry-accepted good practices, the constructed product will meet the specification requirements
Dewater	The act of removing groundwater or lowering the groundwater elevation, using a system of wells and pumps.
Discharge point	The point where the flows in a sewer are discharged to

Drop Connection Manhole	A manhole in which the influent pipe enters from above the effluent invert depth. If the drop occurs in the manhole itself, it is called an "internal" drop manhole. If the drop occurs a few feet upstream of the manhole, it is referred to as an "external" drop.
Drop Manhole	If the upstream pipe is at a greater elevation than the manhole invert then two inlet connections to the manhole are made. One is through the wall at the same grade as the upstream pipe, the other is at the invert so to direct flows through the channel. The invert connection is made by incorporating a pipe drop in the upstream pipe. The pipe drop may be outside or inside the manhole.
DWF	Dry Weather Flow; is the base flow in a sewer prior to rain induced flows
DWI	Dry Weather Inflow; is the result of flow entering the collection system from connected sources which are not caused by rainfall. Typically, this could include water from firefighting, hydrant abuse, street washing, sump pumps etc.
Erf	A demarcated stand (plot) in a suburb or township
Force (Rising) Main	A pipeline that conveys sanitary, combined or stormwater flow under pressure from a pumping (or lift) station to a discharge point
Ground Cover	Distance between the ground surface and the crown of the pipe
IDF	IDF curves provide a summary of a site's rainfall characteristics by relating storm duration and exceedance probability (frequency) to rainfall intensity (assumed constant over the duration)
Infiltration	Water entering the sewer system from surface sources such as manhole covers, open cleanouts, yard or basement drains or roof drains.
Infiltration/Inflow (II)	The total quantity of water from both infiltration and inflow without distinguishing the source.
Inflow	Water entering the sewer system from the ground through such means as pipes, pipe joints, connections, or manhole walls
Inflow	Water discharged into a sewer system and service connections from sources on the surface
Intensity	The rate of rainfall typically given in units of millimeters per hour (inches per hour)
Internal inspection	Means of ascertaining the condition of pipelines, either by visual inspection for man-entry size or by the use of remote control instrumentation
Internal pipe inspection	The television inspection of a sewer line section. A CC-TV camera is moved through the line at a slow rate and a continuous picture is transmitted to an above ground monitor (see also PHYSICAL PIPE INSPECTION)
Invert	The lowest point of the pipe, tunnel, or shaft.
Junction Boxes	Formed control structures used to join sections of storm drains
Lateral	A service line that transports wastewater from individual buildings to a main sewer line
Lateral connection	The point at which the downstream end of a building drain or sewer connects into a larger diameter sewer
Lining with cured-in-place pipes	Method of lining with a flexible tube impregnated with a thermosetting resin, which produces a pipe after resin cure.
Main Sewer	Sometimes called “Trunk Sewer”. A sewer that receives many tributary branches and serves a large area
Major blockage	A blockage (structural defect, collapse, protruding service connection, debris) which prohibits manhole-to-manhole cleaning, TV inspections pipe flow, or rehabilitation procedures

Major System	This system provides overland relief for stormwater flows exceeding the capacity of the minor system and is composed of pathways that are provided, knowingly or unknowingly, for the runoff to flow to natural or manmade receiving channels such as streams, creeks, or rivers
Manhole	A sewer structure designed and constructed in conformance with Municipal Standards which provides access to the sewage collection system for purposes of cleaning, removing blockages, sampling, and video (CCTV) inspection.
Manhole	A structure that allows access to the sewer system.
Manning's Formula	An equation for the value of coefficient c in the Chezy Formula, the factors of which are the hydraulic radius and a coefficient of roughness; an equation itself used to calculate flows in gravity channels and conduits.
Minor System	This system consists of the components of the storm drainage system that are normally designed to carry runoff from the more frequent storm events. These components include: curbs, gutters, ditches, inlets, manholes, pipes and other conduits, open channels, pumps, detention basins, water quality control facilities, etc.
Outfall	A point, location or structure where waste water or drainage discharges from a sewer, drain or other conduit.
Outfall	An outlet to a sewer system
Overflow	(1) The excess water that flows over the ordinary limits of a sewer, manhole, or containment structure. (2) An outlet, pipe, or receptacle for the excess water
PE	Polyethylene; a form of thermoplastic pipe
Permit	The written authorization required pursuant to the Ordinances, rules and regulations of the Agency or applicable District, prior to the installation or construction of specific sewage works under specific conditions at specific locations, or the use of any public sewers.
Pipeline (also pipe)	Portions of the sewer system that are constructed of piping as opposed to manholes and other structures (e.g., trap tank, sumps, etc.)
PVC	Polyvinyl Chloride; a form of thermoplastic Pipe
Redbook	Guidelines for Human Settlement and Planning (CSIR, 2003)
Rehabilitation	(1) All methods for restoring or upgrading the performance of an existing pipeline system. (2) Methods by which the performance of a length of sewer is improved by incorporating the original sewer fabric, but excluding maintenance operations such as tree root or silt removal. Or rehabilitation In situ renovation to improve the performance and extend the life of a defective pipeline, incorporating the fabric of that pipeline. Rehabilitation may be to address structural and/or hydraulic weakness.
Reinforcement	The provision of an additional sewer which in conjunction with an existing sewer increases overall flow capacity.
Return Period	A return period, also known as a recurrence interval (sometimes repeat interval) is an estimate of the likelihood of an event such as a flood or a river discharge flow to occur. It is a statistical measurement typically based on historic data denoting the average recurrence interval over an extended period of time, and is usually used for risk analysis.
Runoff	That part of precipitation carried off from the area upon which it falls. Also, the rate of surface discharge of the above. That part of precipitation reaching a stream, drain or sewer
Saddle	A vertical support mechanism to hold the casing in position while starting (collaring) the bore
Sanitary Sewer	A sewer that conveys the wastewater from two or more properties.

Sanitary Sewer System (Sewerage)	Any system of pipes, pump stations, sewer lines, or other conveyances, upstream of a wastewater treatment plant headworks and which is comprised of more than one mile of pipes and sewer lines, used to collect and convey wastewater to a publicly owned treatment facility
Self-cleansing	A consequence of good hydraulic design when the pipe invert is kept relatively free of sediments by ensuring adequate flow velocities
Sequencing Batch Reactor	Sequencing batch reactors (SBR) are a type of activated sludge process for the treatment of wastewater. SBR reactors treat wastewater such as sewage in batches. Oxygen is bubbled through the mixture of wastewater and activated sludge to reduce the organic matter. The treated effluent may be suitable for discharge to surface waters or possibly for use on land.
Sewage	Wastewater transported in a sewer
Sewer	A pipe or underground open channel foe carrying water or sewage
Sewer Connections	A sewer that discharges into a branch or other sewer and has no other common sewer tributary to it. Typically called “Erf connections”
Sewer Interceptor	A sewer which receives the flow from collector sewers and conveys the wastewaters to treatment facilities.
Sewer Lateral	A building sewer (sometimes referred to as a sewer lateral or house lateral) is the pipeline between the County sanitary sewer line, which is usually located in the street, and the indoor plumbing. The residential building sewer is owned and maintained by the property owner even if it extends into the street or public right of way.
Sewer Outfall	A sewer that receives wastewater from a collecting system or from a treatment plant and carries it to the ultimate disposal area
Sewer Pipe	A length of conduit, manufactured from various materials and in various lengths, that when joined together can be used to transport wastewaters from the points of origin to a treatment facility. Types of pipe are: Acrylonitrile-butadiene-styrene (ABS); Asbestos-Cement (AC); Brick Pipe (BP); Concrete Pipe (CP); Cast Iron Pipe (CIP); Polyethylene (PE); Polyvinylchloride (PVC); Vitrified Clay (VC).
Sewer (Sanitary Sewer)	A sewer that carries liquid and waterborne wastes from residences, commercial buildings, industrial plants, and institutions, together with minor quantities of ground, storm, and surface waters that are not admitted intentionally
Sewer Structure	Any portion of the industrial sewer system including pipeline segments, trap tanks, sumps and other structures; each are assigned a unique number
Sliplining	(1) General term used to describe methods of lining with continuous pipes and lining with discrete pipes. (2) Insertion of a new pipe by pulling or pushing it into the existing pipe and grouting the annular space. The pipe used may be continuous or a string of discrete pipes. This latter is also referred to as Segmental Sliplining
Storm	A rainfall event. (See also - catastrophic rainfall event.)
Storm mains	Primary collector pipelines in the storm water collection system
Storm sewer	A sewer intended to carry only storm waters, surface runoffs, street washwaters, and drainage
Stormwater	Water discharged from a Catchment Area after heavy rain
Stormwater Sewer	A sewer that conveys stormwater runoff from two or more properties and stormwater runoff from roofs, paved areas and roads within the catchment area of the sewer
Surcharged sewer	A gravity sewer that is overloaded beyond its pipe full flow capacity such that the flow becomes pressurized

Trenchless Technology	A family of construction techniques for installing or rehabilitating underground infrastructure with minimal disruption to surface traffic, businesses, and residents. Also includes technologies for inspection, leak location, and leak detection with minimal disruption and minimal excavation from the ground surface.
Trunk Sewer	A sewer, into which at least two branch sanitary, combined or stormwater sewers connect. It conveys the flow to the Interceptor sewer. The trunk sewer is the longest connection sewer in any drainage basin. Also sometimes known as a "main" sewer.
Wastewater	The liquid conveyed in sewer system
Wastewater	The spent or used water of a community or industry which contains dissolved and suspended matter.
Watershed	(1) A defined geographical area, usually delineated by high ground that drains to a watercourse. (2) Region or area contributing to the supply of a stream or lake; drainage area, drainage basin, catchment are
WWTP	Wastewater Treatment Plant

2.3.1 Disclosure Classification

Controlled Disclosure: Controlled Disclosure to External Parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Definition	Description
AASHTO	American Association of State Highway and Transportation Officials
AMSL	Above Mean Seal Level
ASCE	American Society of Civil Engineers
BS	British Standards
CCTV	Closed-circuit Television
CMD	Construction Management Department
CIPP	Cured-in-Place Pipe
CoE	Eskom's Centre of Excellence
CSIR	Council for Scientific and Industrial Research
DWA	Department of Water Affairs
DWH	Dams, Waterways and Hydro
DWS	Department of Water and Sanitation
EDWL	Engineering Work Delivery Unit Manager
GFRP	Glass Fibre Reinforced Plastic
HDPE	High Density Polyethylene
IDF	Intensity, Duration, Frequency
LDPE	Low Density Polyethylene
LPE	Lead Project Engineer
LPS	Low Pressure Services
NHBRC	National Home Builder Registration Council
NWA	National Water Act
PDD	Project Development Department

PEM	Project Engineering Manager
PI	Plasticity Index
PMF	Probable Maximum Flow
PVC-U	Unplasticised chloride
SANCOLD	South African National Committee on Large Dams
SANRAL	South African National Roads Agency Limited
SANS	South African National Standards
SBR	Sequencing Batch Reactor
SDF	Spatial Development Framework
TDAC	Technical Document Authorization Committee
TR	Technical Report
uPVC	Polyvinyl Chloride Pipe

2.5 ROLES AND RESPONSIBILITIES

2.5.1 The Role of a Centres of Excellence (CoE)

The role of the Engineering CoE is provided below:

- Apply its expertise, skill and processes to produce a high quality output of exceptional standards in line with the organizational requirement.
- Assist in providing project activities and man hours for project preplanning.
- Provide engineering resources to perform the engineering effort.

2.5.2 The Engineering Design Work Lead

- The EDWL has the following reporting lines:
- Accountable for the strategy and all design related activities to the Plant Engineering General Manager. The Centre of Excellence Engineering Manager will prepare, review, assess and score the performance contract of the EDWL.
- The EDWL is appointed by the Engineering Work Delivery Unit Manager in conjunction with the relevant Centres of Engineering Excellence and Authorised by the Plant Engineering General Manager (GM).
- Reports to the Project Engineering Practitioner for technical delivery achieved to baseline scope, schedule and cost.

2.5.3 The Project Engineering Manager

The Project Engineering Manager (PEM) has the following reporting lines:

- Accountable for the schedule, scope and cost of engineering activities. The Project Engineering Area/Portfolio Senior Manager will also prepare, review, assess and score the performance contract of the PEM.
- The PEM is appointed by the Project Engineering Senior Manager and Authorised by the Project Engineering General Manager (GM).
- Reports to the PDD or CMD Manager for engineering delivery achieved to baseline scope, schedule and cost.

2.5.4 The Project Engineering Controls

- The Project Engineering Controls should know the functionality and requirements associated with developing a proper basis of estimate, Cost breakdown structure, level II scheduling, direct and indirect costing, Parametric and factoring approaches. Must be able to produce and communicate the methodology used to arrive at the man hours and costs associated with the estimates. The candidates must have knowledge and hands-on experience with Cost Breakdown Systems (CBS), cost reporting, trend/change management, budget control, forecasting (multiple methods).

2.5.5 The Lead Discipline Engineer

- The LDE has the following reporting lines:
- Accountable for all design related activities to the Centre of Excellence Engineering Manager. The Centre of Excellence Engineering Manager will also prepare, review, assess and score the performance contract of the LDE.
- The LDE can be a Professional Engineer or under supervision of a Professional Engineer who will take accountability for the design.
- Reports to the Engineering Design Work Lead (EDWL) for day to day activities, service delivery and logistics. However leave requests will be addressed with the Centre of Excellence Engineering Manager.

2.6 PROCESS FOR MONITORING

Monitoring and Maintenance is to be done by the owner of the drainage and sewer infrastructure.

2.7 RELATED/SUPPORTING DOCUMENTS

None

3. DRAINAGE AND SEWERAGE INFRASTRUCTURE DESIGN STANDARD

Section 3.1 deals with the Design Standard for Stormwater Design and Section 3.2 deals with the Design Standard for Sewerage Design.

3.1 DESIGN STANDARDS FOR STORMWATER DESIGN

3.1.1 Objective

The objective for this specification is to ensure all stormwater designs are approached and designed according to South African codes and Legislation. This will also standardise Eskom stormwater designs and water management plans.

The design activity is concerned with establishing the source, quality and magnitude of the medium to be drained:

1. If the source is rainfall, or naturally occurring flowing water, a hydrology study, which will consider climate change impacts, is requested.
2. In the case of uncertain quality of medium, a chemical analysis is requested.
3. No studies would be necessary in the case that the quantity and quality of the medium to be drained is known.

3.1.2 Codes and Legislation

The following policies, codes and legislation are used during any stormwater design (see Table 3.1) and should be considered as it impacts stormwater master planning.

Table 3.1 : Codes and legislation needed for stormwater designs

Description	Policy, Code and Legislation
Constitution of the Republic of South Africa	Act No 108 of 1996
National Water Act (NWA)	Act No 36 of 1998
Environmental Conservation Act	Act No 73 of 1989
National Roads Act	Act No 54 of 1971
National Building regulations and Building Standards Act	Act No 103 of 1997
Conservation of Agricultural Resources	Act No 43 of 1983
SANRAL Drainage Manual 6^{th} Edition	ISBN 978-0-620-55428-2
Guideline for Human Settlement Planning and Design-Volume 1 and 2	ISBN 0-7988-5498-7
Manhole Design	SANS 1200 LD

3.1.3 Design Process

The stormwater management and design system specification will discuss the process to follow when designing a stormwater management system. Figure 3.1 below starts with the Flood Risk identification process and then progresses to the Flood Risk Assessment, which then provides the return period and resuts in being used for the hydrology study. These calculations will establish the design layout and final detailed calculations. Figure 3.1 is used in conjunction with sections 3.1.3.1 to 3.1.3.5.

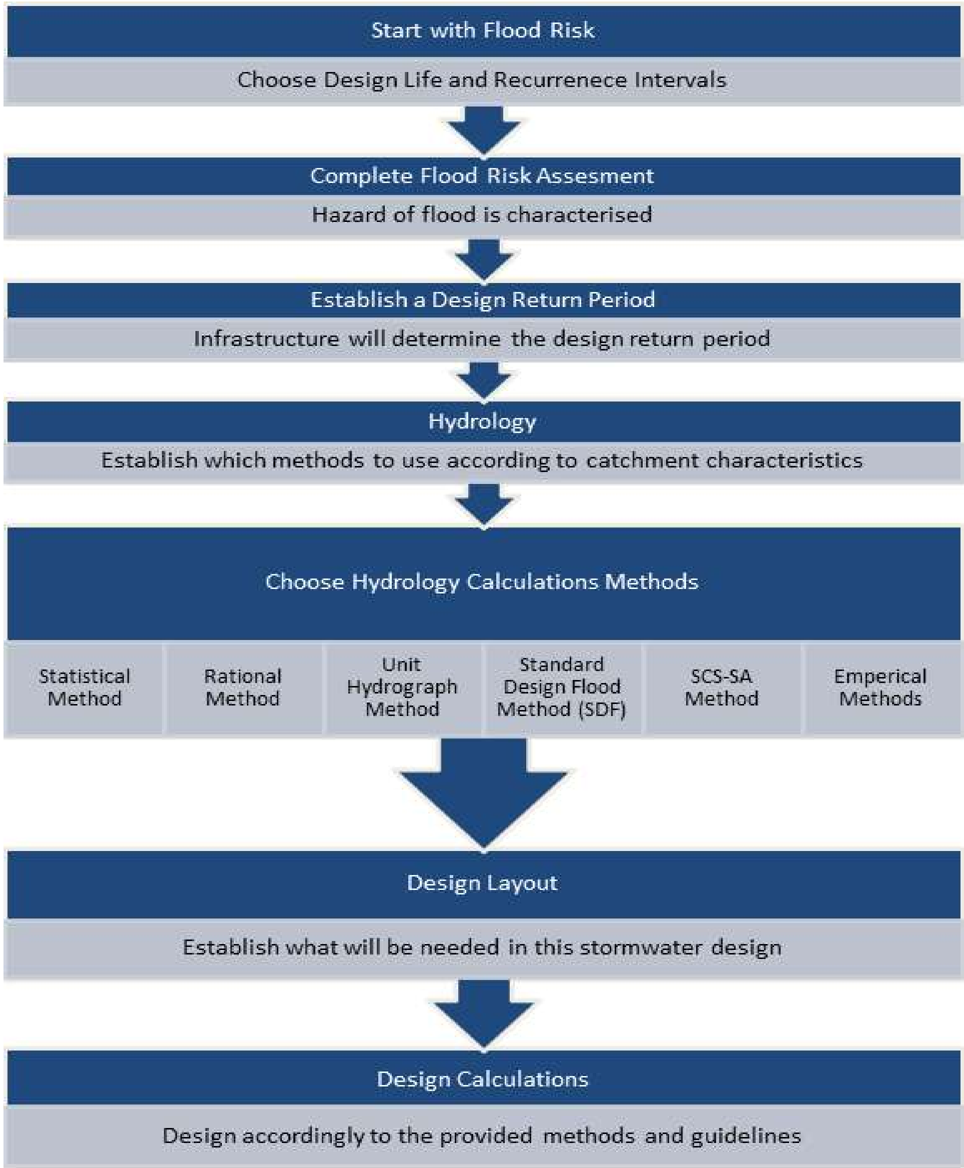


Figure 3.1: Design process flow diagram for stormwater systems

3.1.3.1 Flood Risk

Risks of floods are measured according to likelihood and consequences. A comparison of the risk of a flood with a specific recurrence interval reoccurs at least once during the design life. The comparison is presented below (see Table 3.2):

Table 3.2 : Flood Risk Design Life (HRU, 1979)

Recurrence Interval (years)	Design Life (years)							
	1	2	5	10	15	20	25	50
10	10%	19%	41%	65%	79%	88%	93%	99.5%
20	5%	10%	23%	40%	54%	64%	72%	92%
50	2%	4%	10%	18%	26%	33%	40%	64%
100	1%	2%	5%	10%	14%	18%	22%	40%

Table 3.2 states what the probability is of the system failing at a Recurrence Interval for a specific design life; e.g.: If I have a design life of 50 years and we work on a 50 year recurrence flood interval, the probability of the system failing in that 50 year period is 64%.

3.1.3.2 Flood Risk Assessment

Flood risks can be assessed according to the hazard rating and the cost of the flood damage. Figure 3.2 uses the flow velocity (m/s) and depth (m) of the channel and provides the hazard classification according to the following descriptions:

1. Low Hazard – No difficulty transporting individuals away to safety.
2. High Hazard – Possible danger to personal safety of individuals.

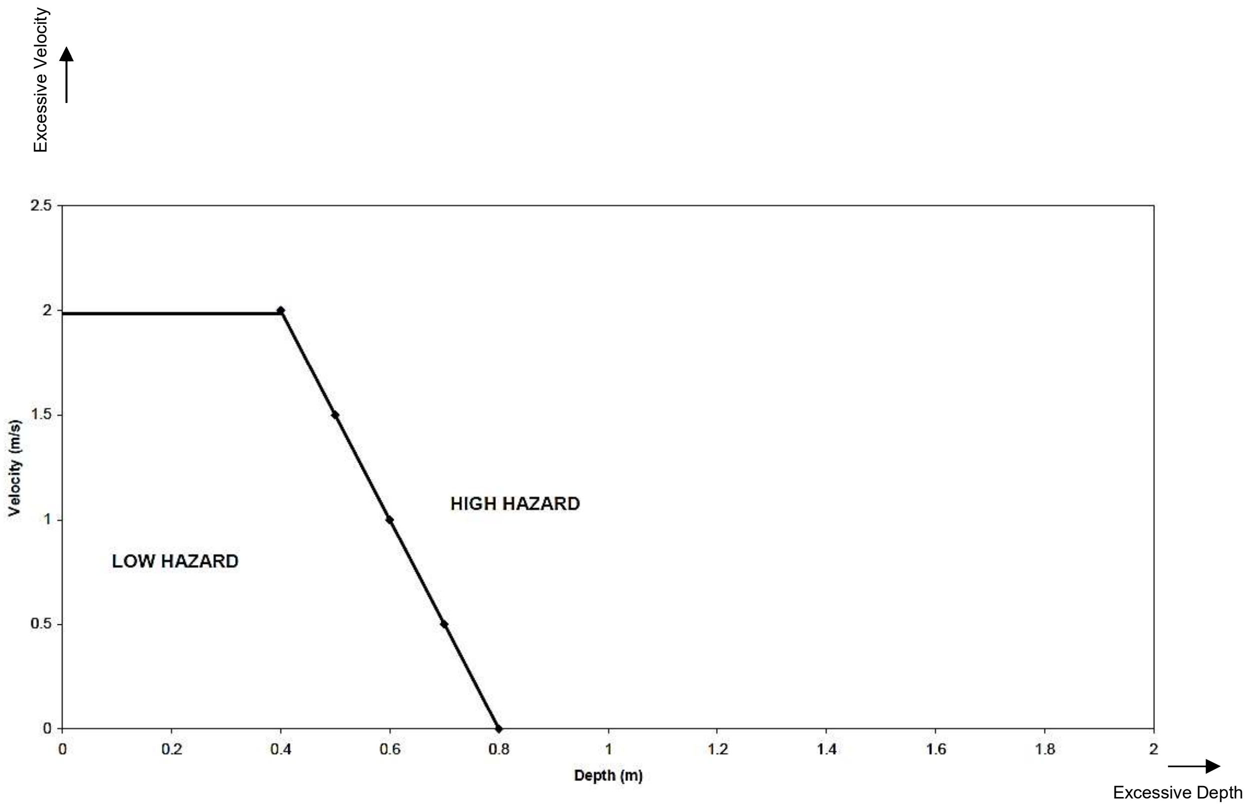


Figure 3.2 : Flood hazard zones (CCT, 2009)

3.1.3.3 Design Return Period

Design return periods for various stormwater related infrastructure scenarios are provided. In the case of road crossings, Table 3.3 (SANRAL Drainage Manual, 2013) provides return period classes for a 20-year recurrence interval. It must be noted that road crossings are generally designed for a 20 year recurrence period and are increased due to road surface changes.

Table 3.3 : Road crossings proposed return periods (SANRAL Drainage Manual, 2013)

Road Class	**Proposed return period (T) based on the magnitude of the Q_{20} flood (years)**		
	Q_{20} < 20 m^3/s	**20 m^3/s < Q_{20} < 150 m^3/s**	**Q_{20} > 150 m^3/s**
Primary Distributer	50	$T = 42.31 + 0.385Q_{20}$	100
Regional Distributer	20	$T = 15.39 + 0.231Q_{20}$	50
District Distributer	10	$T = 8.46 + 0.077Q_{20}$	20
District Collector	5	$T = 4.231 + 0.0385Q_{20}$	10
Access Roads	2	$T = 1.539 + 0.0231Q_{20}$	5
Non-motorised/ Access ways	2	$T = 1.539 + 0.0231Q_{20}$	5

According to Guidelines for Human Settlement and Planning (CSIR, 2003) urban development and road drainage return periods can be calculated accordingly. The urban design for stormwater is divided into major and minor stormwater systems.

Major System Concept: Major system (see Table 3.4) conveys runoff rates and volumes for a 1 in 100 year rainfall event which exceed the capacity of the minor system. The major drainage system consists mainly of overland drainage conveyance elements.

Table 3.4 : Major systems design flood recurrence intervals (CSIR, 2003)

Land Use	Design Flood Recurrence Interval
Residential	50 years
Institutional (e.g. Schools)	50 years
General commercial and Industrial	50 years
High value central business districts	50-100 years

Minor System Level of Service: Minor system (see Table 3.5) consists of the pipe network, plus gutters and inlets which provide a convenience system to rapidly carry away storm runoff from road surfaces for minor rainfall events. Storm mains which service areas of 0.3 km^2 or less are to be designed to convey runoff from 1 in 5 year and more frequent rainfall events. Mains servicing areas greater than 0.3 km^2 are to be designed to convey 1.25 times the rate of runoff which would occur in a 1 in 5 year rainfall event.

Table 3.5 : Minor systems design flood recurrence intervals (CSIR, 2003)

Land Use	Design Flood Recurrence Interval
Residential	1-5 years
Institutional (e.g. Schools)	2-5 years
General commercial and Industrial	5 years
High value central business districts	5-10 years

In the case of a natural watercourse and channel design, Tables 3.6 and 3.7 should be used for the return periods. When one designs for major watercourses and channel systems within urban developments one should consider the flood plains and if they can withstand flows provided by the channel.

For Table 3.6 catchment areas larger than 1 km^2 are considered (SANRAL Drainage Manual, 2013):

Table 3.6 : Natural watercourses and channel design return periods for catchments larger than 1 km^2

Development	Design return periods for Major systems (years)		
	Main channels only (no flood plain)	Main channels plus flood plain	
		Main channel	Flood plain
Residential	50	20	50
Business/ commercial	50-100	20	50
CBD	50-100	50	100

Typical guidelines used for catchment areas larger than 1 km^2 are provided in Table 3.7 (SANRAL Drainage Manual, 2013).

Table 3.7 : Natural watercourses and channel design return periods for catchments smaller than 1 km^2

Development	Design return periods for Major systems (years)		
	Main channels only (no flood plain)	Main channels plus flood plain	
		Main channel	Flood plain
Residential	20	10	20
Business/ commercial	20-50	10	20
CBD	50	20	50

Stormwater storage facilities that retain, detain or any form of dam that forms part of a drainage system should be designed according to the relevant standards and design guidelines. South African National Committee on Large Dams (SANCOLD, 1991) guidelines can be used to establish relevant assessment standards and designs. Design return periods should be confirmed with all SANS codes and approved guidelines before any design commences.

3.1.3.4 Catchment Hydrology and Stormwater System Modelling

The scope of the hydrology study is dependent on the infrastructure design. In the case of stormwater drainage the study shall be confined to rainfall, climate change impact and flow studies. In the case of dams, river channels and pumped storage scheme design, the study shall also include flood hydrology.

There are a few methods available to design the flood peaks. These methods have been developed for certain regions and flood events.

Table 3.8 Lists the methods, input data required and maximum catchment areas needed to design the flood peaks. SANRAL Drainage Manual should be used to calculate the flood peaks as all the methods are described in full detail. The Maximum Peak Flood calculated using the various methods shall be used for the design.

It should be noted that for uncomplicated designs the Rational Method is preferred, although other methods should be used to check the design.

Table 3.8 : Application and limitations of flood peak calculation methods (Drainage Manual, 2013)

Method	Input Data	Recommended maximum area (km^2)	Return period of flood that could be determined (years)
Statistical Method	Historical flood peak records are used	No limitation (large areas)	2-200 (depending on the rainfall record length)
Rational Method	Catchment area, watercourse length, average slope, catchment characteristics, design rainfall intensity (3 alternative methods)	Usually smaller than 15, depends on method of calculation rainfall intensity	2-200, PMF
Unit Hydrograph Method	Design rainfall, catchment area, watercourse length, length of catchment centroid, MAP, veld type and synthetic regional unit hydrograph	15 to 5000	2-100, PMF
Standard Design Flood Methods (SDF)	Catchment area, watercourse length, slope and SDF basin number	No limitations	2-200
SCS-SA Method	Design rainfall depth, catchment area, Curve number=f (soil, land cover),catchment lag	Smaller than 30	2-100
Empirical Methods	Catchment area, watercourse length, distance to catchment centroid, MAP	No limitations (larger areas)	10-100, RMF

The Flood peak methods can be calculated step by step using Appendix 3C of the SANRAL Drainage Manual (Drainage, 2013). One should just remember to use the Design rainfall and flood estimation in South Africa (TR 102) when working with the SDF method.

A report should be provided on the hydrology study that provides information that explains the purpose and the approach of the modelling, assumptions made, climate change impact studies and the scenarios simulated. Abnormalities should also be recorded. The report should reference the specific version of the model or program it was based on.

3.1.3.5 Designs

The drainage design can be classified as either an open system channel or a closed system. This activity is concerned with finding a suitable system and routed for the drainage system. The following should be considered:

Table 3.9 : Catchment characteristics for design consideration

Design Considerations	
a) Topography	b) Safety
c) Station layout	d) Access
e) Cost	f) Medium to be drained
g) Environmental factors including Climate Change Impacts	h) Geometric constraints
i) Space constraints	j) Maintenance
k) Transfer distances	l) Flow

If the system is gravity based the layout primarily should consider the typical design criteria for a drainage system, e.g. distance between inspection points or specifications regarding the change of direction.

The following design criteria should be considered when designing underground drainage lines:

- Pipe Loading Calculations
- Pipe Deflection Calculations
- Pipe Buckling Calculations
- Pipe Wall Crushing Calculations

Other design criteria are included in the subsequent subsections.

3.1.3.5.1 Flow Metering

Flow measuring devices meters installed on any system for process control purposes shall have an accuracy of 5% or better. It should be noted that Annubar-type meters, or similar flow devices, shall not be used.

All strategic water metering shall be incorporated into an active water management database for diagnostic and accounting purposes. The power supply to each of the raw water flow meters must be supplied from different sources and the overall design shall be such that the flow can be bypassed to ensure that the flow meters can be removed from the system for maintenance purposes.

3.1.3.5.2 Road bridges

Low-level river crossings, Bridge Design and major culvers shall be designed using SANRAL drainage Manual (Drainage 2013) Chapter 7 and 8.

3.1.3.5.3 Surface run-off on Roadways, shoulder drainage design and kerbs

The road drainage design considers local precipitation that runs across a road surface. The flow ends where the accumulated stream is released into an existing natural or man-made waterway without any risk of downstream flooding.

Acceptable risk is expressed in terms of the water surface levels not being exceeded during flood with the given return periods.

When designing a road, the flow depth of surface run-off across road surfaces is usually not a primary concern at design. Thus the following factors should be considered when designing for the drainage system:

1. Vehicle speed, wheel load, type of tyre and tyre pressure.

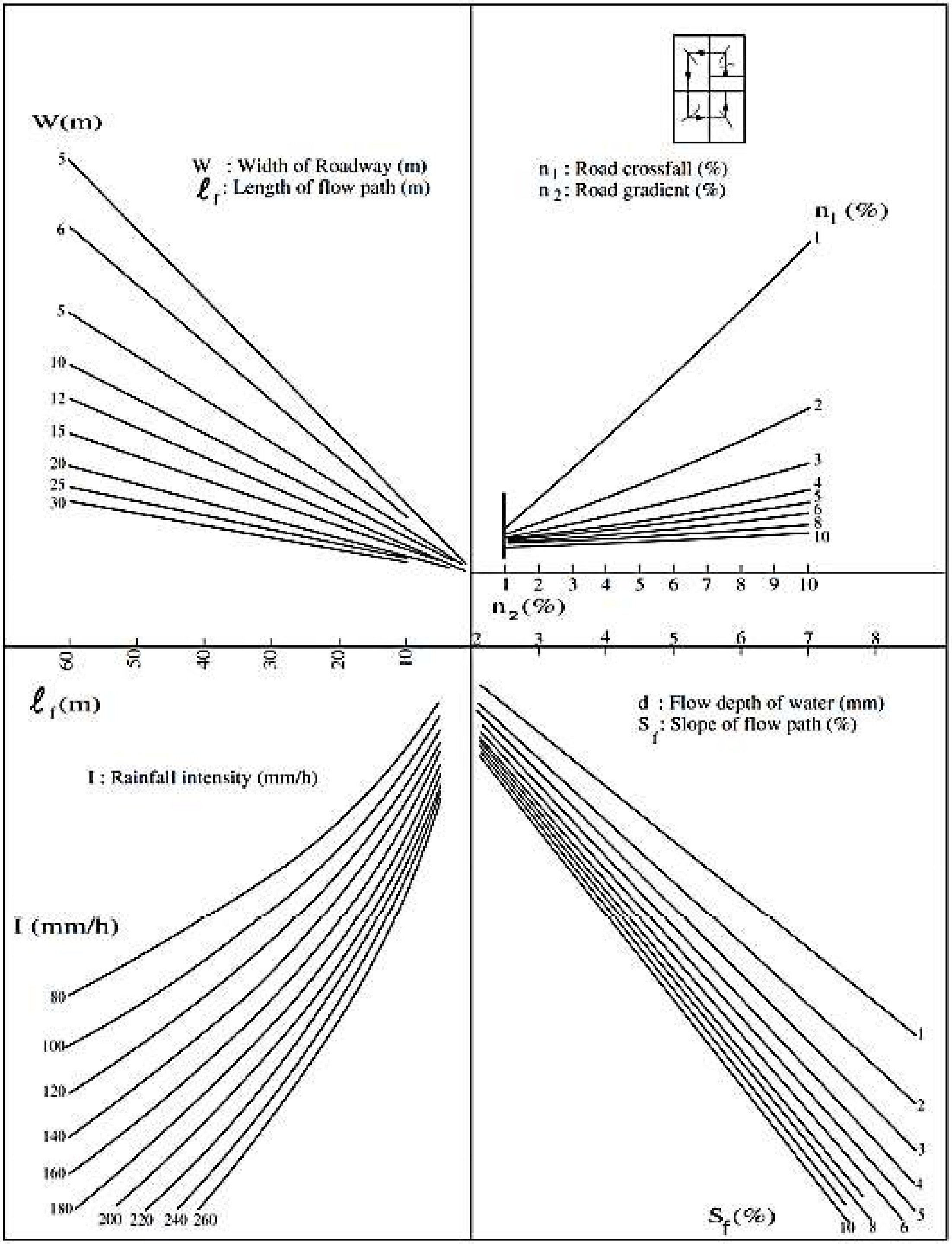
To ensure a reduction in hydroplaning the speed should be less than 80 km/hr. The wheel load, type of tyre and tyre pressure also affects hydroplaning, but due to the wide variety of parameters affecting hydroplaning these different aspects are ignored. It should be noted that these parameters are still considered when designing the geometrics of the road.

2. Depth of flow

Depth of flow varies in the analysis of roadway and shoulders flow. The following recommendations are made for surface flow (Drainage Manual, 2013):

i. Flow depths for 1:5 year storm should not exceed 6 mm.
ii. The minimum slope along the flow path should be 2%. If the road surface is wider then a normal cross-fall of 2.5% can be expected.

Figure 3.3 can be used to determine the depth of flow on the road surface.



$$l_f = w\left(1 + \left(\frac{n_2}{n_1}\right)^2\right)^{0.5} \quad (a) \qquad d = 4.6x10^{-2}\left(l_f I\right)^{0.5}\left(S_f\right)^{-0.2} \quad (b) \qquad (1)$$

Figure 3.3 : Depth of road surface flow (Laminar flow conditions assumed) (SANRAL Drainage Manual, 2013)

Using the frequently used n_1 value of 2% and the n_2 value of not less than 1%, one can read of the Length of the flow path (l_f) using the road width (W) or by just calculating the length of flow using equation 1a.

With the length of the flow path (l_f) available, one uses the rainfall intensity (mm/hour) and the slope of the flow path to determine the final depth of the surface flow.

The surface water depth is compared to Table 3.10 to ensure that the road classification concurs with the maximum encroachment and Figure 3.4 to establish if the maximum depth of the side channel correlates to the surface depth value. Kerbs are designed to collect surface run-off and to discharge flows at specific points to control traffic risks and protect erodible areas such as embankments.

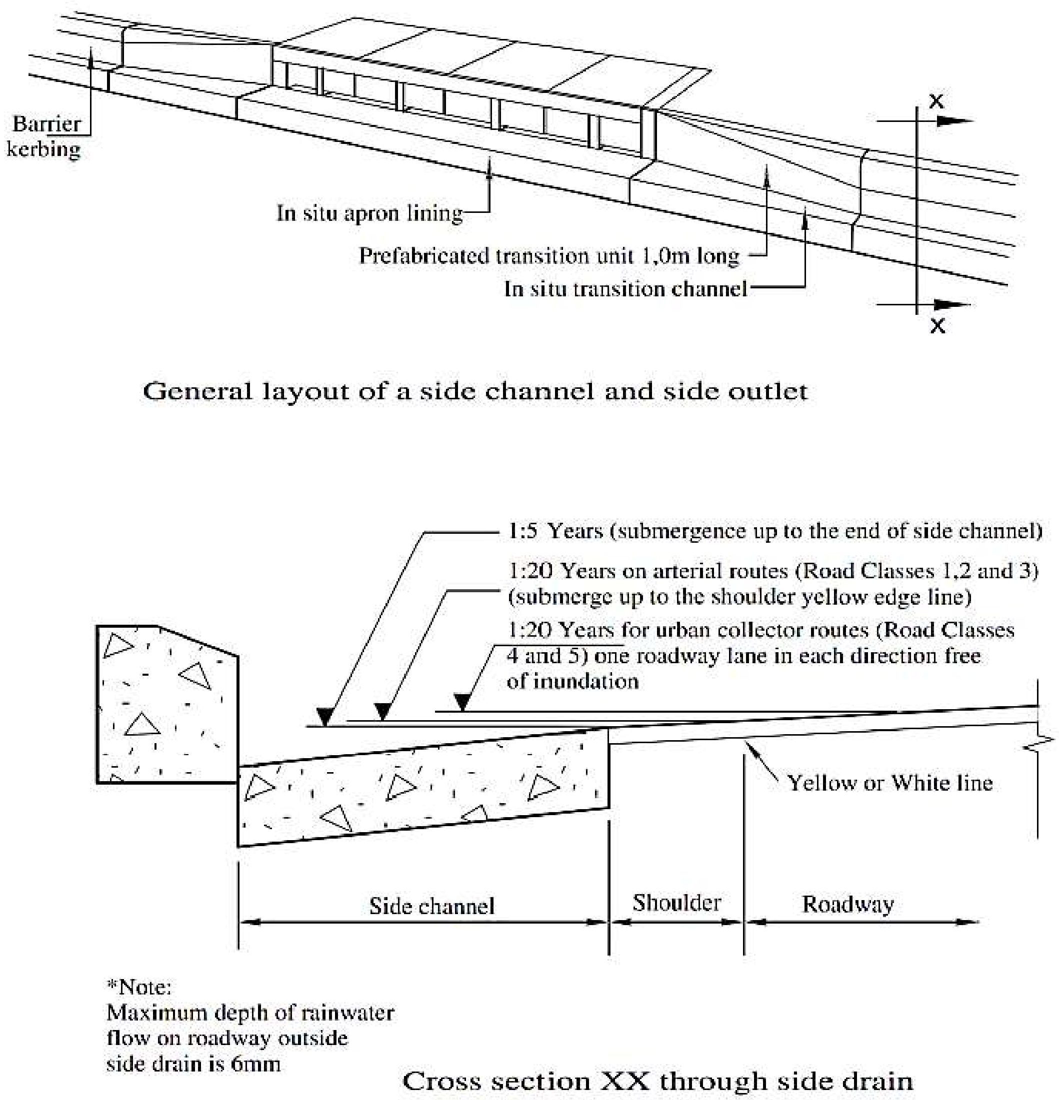


Figure 3.4 : Maximum depths allowed for side channels (SANRAL Drainage Manual, 2013)

Table 3.10 : Maximum Depths according to road classification

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.

To calculate the flow depth in the kerb Figure 3.5 is used to determine the parameters for Figure 3.6.

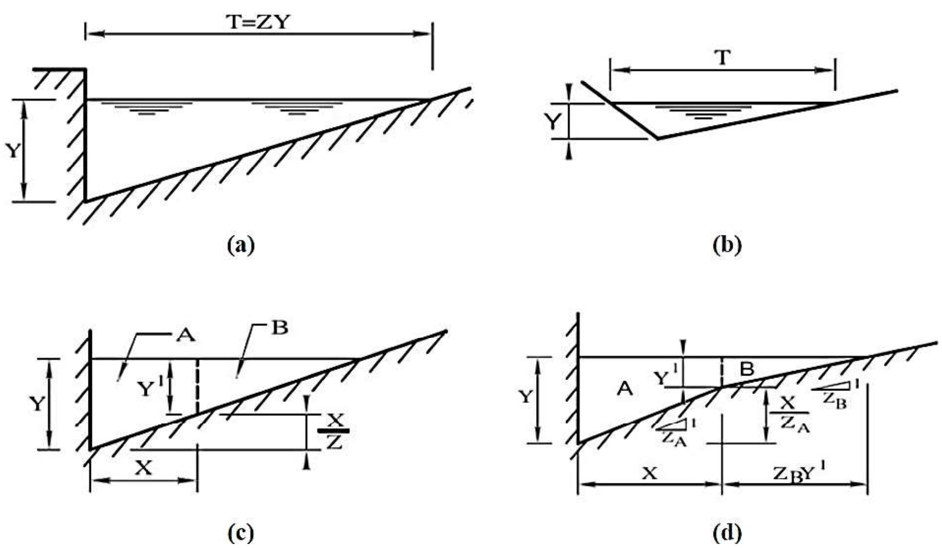


Figure 3.5 : Typical triangle kerb cross-section (SANRAL Drainage Manual, 2013)

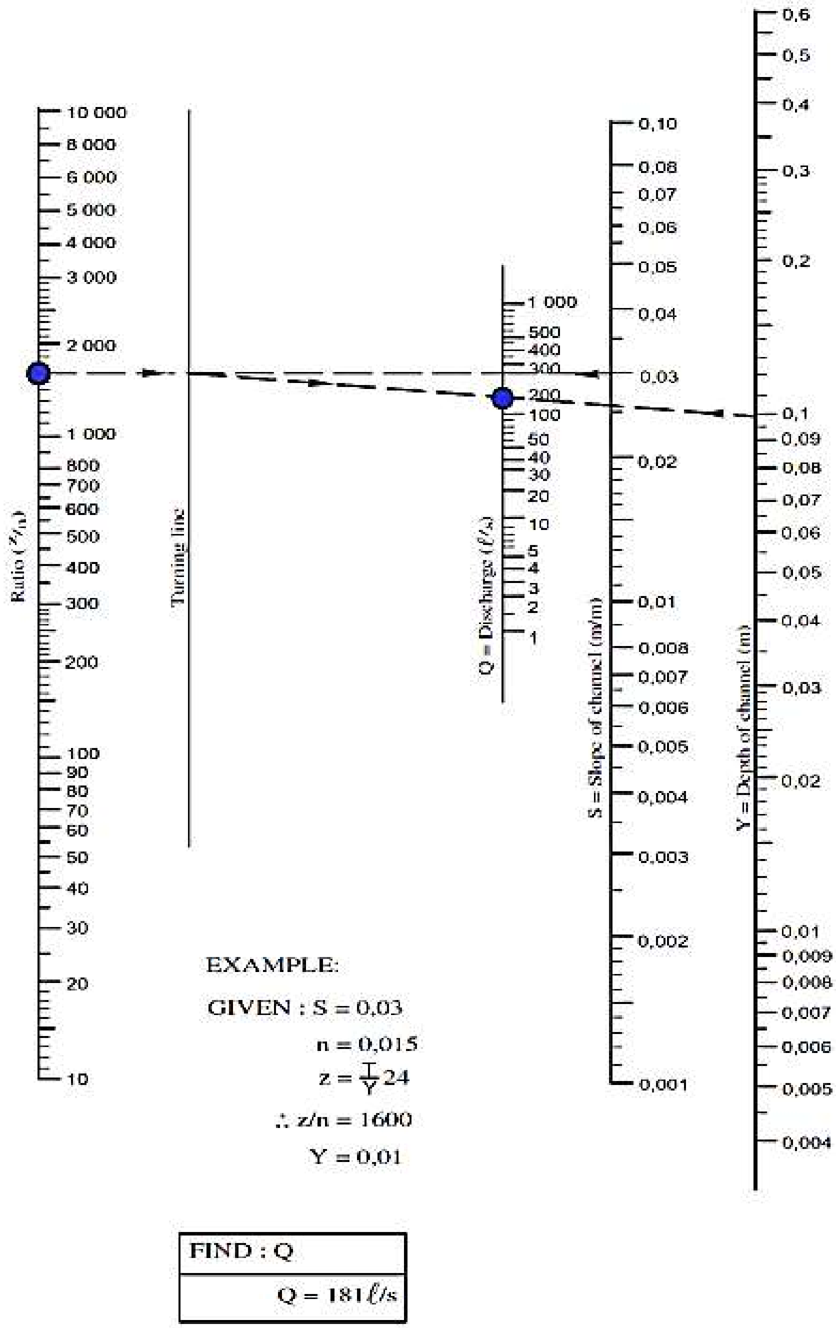


Figure 3.6 : Example of Nomogram for flow in triangular channels (SANRAL Drainage Manual, 2013)

Using Figure 3.5 the dimensions for the channel are given, including the channel slope. By calculating the z/n value one can use Figure 3.6 and draw a line between the slope and the z/n value. This line crosses the turning line. As the Y depth was calculated using Figure 3.3, one connects the depth with the turning line and thus a discharge value for a triangular channel is measured.

Maximum Spacing of outlets: Runoff shall not be required to flow a distance greater than 200 m alongside channels and median drains without reaching a catch basin. In lanes and walkways, runoff shall not be required to flow on the surface a distance greater than 300 m for channels above cutting.

Figure 3.4 and Table 3.10 must be used to classify the side channel and estimate the maximum flow depth.

3.1.3.5.4 Stormwater pipes (type, size, inlet and outlet levels)

For pipe infrastructure there are a few design aspects that have to be considered when assessing the flow capabilities of the pipe system design. Material selection is dependent on quality of the medium, abrasiveness, pipe loading and cost.

Concrete pipes are mainly used for stormwater designs. In some cases an aggressive medium, such as sewage, requires a pipe material other than concrete.

One should always consider the design at hand and what the best, cost effective solution will be, based on life cycle costing and not only construction cost. One can also consider Glass Fibre Reinforced Plastic (GRP), Ductile Iron, Steel and HDPE piping materials for industrial and heavy duty pipeline designs.

In case no suitable pipe material for the specific design is available, one should consider corrosion protection linings. Different pipelines have different corrosion protection. The following section provides information on possible protection methods and linings.

These are a few corrosion methods:

a) Coatings – barrier against electrolyte
b) Insulation – breaks electrical circuit
c) Inhibitors – modify electrolyte
d) Anti-corrosion coatings – barrier plus inhibition
e) Pipeline coating/wrapping – barrier
f) Cathodic protection – single electrode
g) Sacrificial Anodes

And for Primary pipeline protection these materials and chemical liners/coatings can be used for protection.

h) Bitumen/Coal Tar Enamel Fibreglass
i) Polymer Modified Bitumen
j) Tape Wrapping (not suitable for large bore thin walled pipe)
k) New Generation Liquid Systems (Polyurethane & Epoxy)
l) Fusion Bonded Medium Density Polyethylene (Sintakote)
m) Fusion Bonded Epoxy/Dual Layer FBE System
n) Trilaminate Polyethylene Coating (3LPE)

The thickness of the corrosion protection layer is dependent by the chemical compositing of the transported medium, but it should be noted that the thickness and type of lining affects the flow velocities and the pipe roughness.

All Stormwater pipelines are suggested to have an Internal Diameter (ID) of 300 mm pipe and a 375 mm in diameter pipe for a road reserve pipeline. There shall be designed and constructed to give mean velocities, when flowing full, of greater than 0.6 m/s based on Manning's Formula.

Flow velocities of 0.9 to 1.5 m/s are recommended and designs based on the lower velocities are to be justified on the basis of feasibility or unwarranted cost impacts (Drainage Manual, 2013).

Low velocities will increase siltation. To ensure siltation is maintained at bare minimum, Table 3.11 should be used accordingly.

Table 3.11 : Pipe diameters with gradients to ensure minimal siltation (Redbook)

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	1000
1050	440	1250
1200	520	1500

3.1.3.5.5 Friction Losses (h_f)

According to Darcy-Weisbach's equation the friction head can be calculated with:

$$h_f = \frac{8\lambda L Q^2}{\pi^2 g D^5} \qquad \textbf{(2)}$$

Where:

h_f is friction loss (m)

λ is the pipe friction factor

L is the length of the pipeline (m)

Q is the flow (m^3/s)

g is the Gravity constant of 9.81 m/s^2

D is the Internal diameter of the pipe (m)

To calculate λ the Colebook-White transitional formula can be used (CHADWICK, Andrew et al., 2004). Moody also developed a formula for the Moody diagram (see Figure 3.7) to calculate the friction factor.

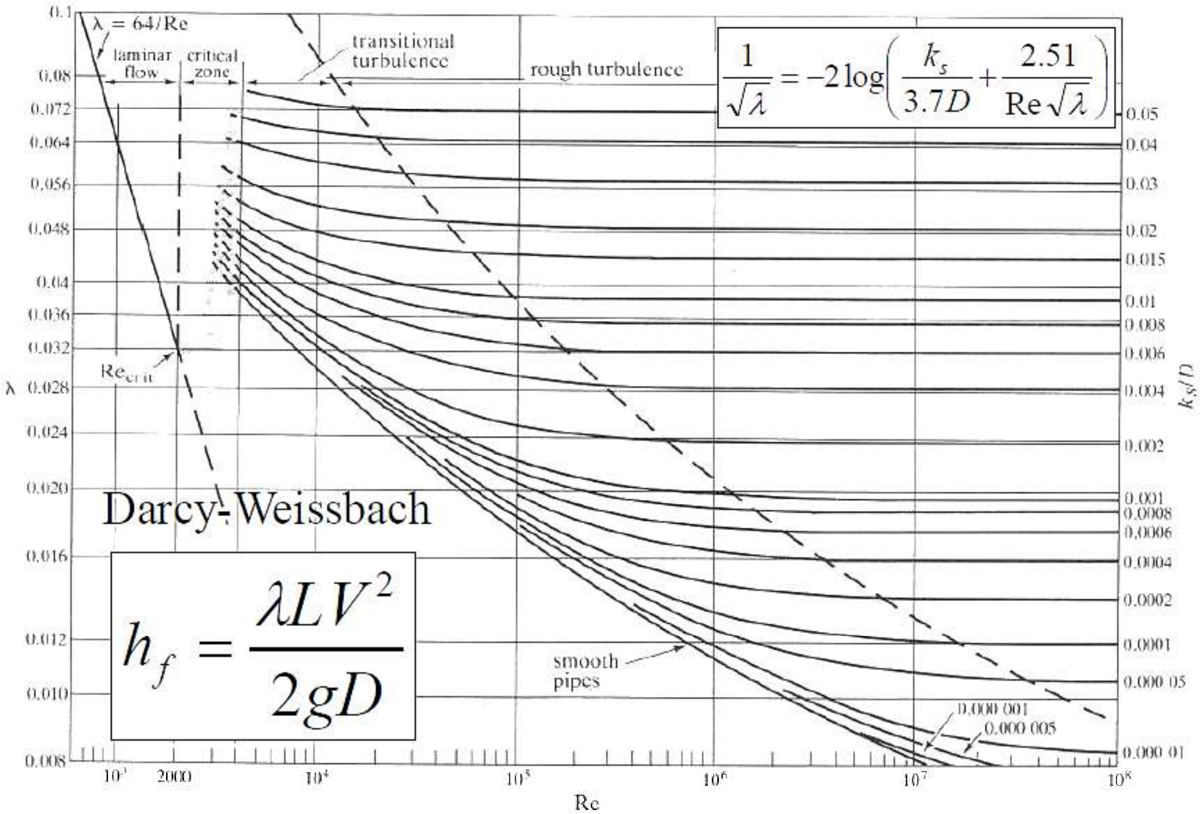


Figure 3.7 : Moody Diagram

Moody Formula: $\boldsymbol{\lambda = 0.0055\left[1 + \left(\frac{20000k_s}{D} + \frac{10^6}{Re}\right)^{1/3}\right]}$ (CHADWICK, Andrew et al., 2004)

Where:

k_s is the roughness coefficient (m)

D is the pipeline diameter (m)

Re is Reynolds Number

3.1.3.5.6 Local Head Losses (h_L)

According to Chadwick and Morfett the equation below provides the secondary head losses:

$$\boldsymbol{h_L = \frac{k_L V^2}{2g}} \qquad \textbf{(3)}$$

Where:

h_L is the local head loss (m)

k_L is the total local head loss coefficient

V is the flow velocity (m/s)

g is the Gravity constant of 9.81 m/s^2

The total head needed for the design of the stormwater system can be calculated with the following formula:

$$H = \Delta z + h_f + h_L \tag{4}$$

Where:

H is the Total head needed for design (m)

h_L is the local head loss (m)

h_f is friction loss (m)

The Δz in Equation 4 is the total height from the invert level to the outlet level. The friction losses and the secondary losses can be calculated with the formulas and tables provided above. If the stormwater has to be pumped (any pump system) then the same principle will be used to calculate the pump head.

3.1.3.5.7 Valve Design and Location Allocation

Valves and placed into the system to provide inspection sections and to reduce air pressure build-up in large pipelines. Using the Joukowski Formula, the head and pressure class for the pipeline can be calculated. Joukowski's formula is as follows:

$$H = \frac{av}{g} \tag{5}$$

Where:

a is the wave speed (m/s) for GRP, HDPE, uPVC and Steel pipes
v is the velocity of fluid in pipeline (m/s)
g is the Gravity constant of 9.81 m/s^2

$$c = \sqrt{\frac{K}{\rho}} \tag{6}$$

Where:

K is bulk modulus or stiffness coefficient for GRP, HDPE, uPVC and Steel pipes

ρ Is the density of the liquid

To establish if the stormwater has a specific pressure class to determine the pipe class, the $\Delta P = \rho gH$ value and Joukowski value is combined to provide the pipe pressure class in Bar. According to this pipe class classification the valve position and class can be determined.

3.1.3.5.8 Air Valve and Scour Valve Design

Valves are not always needed as stormwater systems can be gravity flow based. In case a pressured system is needed the positioning of the air valve is placed on the yellow crossed sections in Figure 3.8.

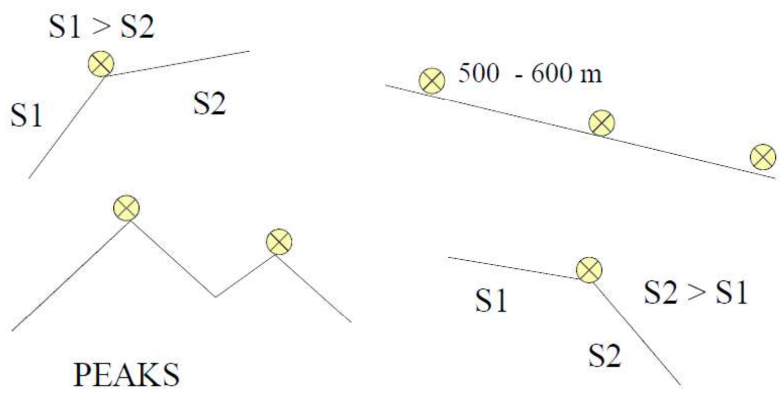


Figure 3.8 : Valves Positioning Guidelines

There should also be considered what the effect of bursting and scour will be in the drainage system. The design of the scour valves and bursting valves are designed with the following flows. The scour flow formula and the Bursting flow follows. The scour valve and bursting valve size is chosen according to the flow out of the pipeline and the nominal diameter of the pipeline.

$$Q_{drain} = C_d(2g\Delta h)^{0.5} \left(\frac{\pi D^2}{4}\right) \quad (7)$$

Equation 7 determines the rate of drainage in the pipeline. This will result in the sequence the air valves will function and drainage to occur in case a blockage or failure of flow in the pipeline takes place.

$$Q_{burst} = \left[\frac{g\,\pi D^5\,S_0}{8\,\lambda}\right]^{0.5} \left(\frac{A_{rupture}}{A_{pipe}}\right) \quad (8)$$

When a pipe bursts the medium flows from the pipe and increases the chance of collapse. To prevent the pipe from collapsing due to developing sub-atmospheric pressures, air is allowed to enter the pipeline at a controlled rate to prevent low pressures that will displace the seals or chances of pipe failure.

Since it is impossible to determine where a pipe break or bursts will occur, one will analyse all the low lying positions. Thus the slope of each pipe section and Q_{Burst} is calculated to determine the maximum flow in the pipeline. This will ensure that the outlet points and pipeline is designed accordingly.

3.1.3.5.9 Manholes

Manhole should be designed according to SANS 1200 LD or the Guidelines for Human Settlement Planning and design manual. It should be noted that the manhole spacing is determined from a maintenance perspective.

3.1.3.5.10 Station drains

Station drains depend on what site conditions are but all drains that accumulate stormwater shall drain towards an oil separation facility. This facility shall have the capacity to effectively remove the spilled oil from drains water. It shall consist of:

1. A suitable silt settling facility to safeguard against silt deposition,
2. An adequately sized attenuation dam to prevent flow surges,
3. Storage, i.e. untreated stormwater or drain water and recovered oily product or oil,
4. Access roads to effectively operate and load the recovered oil for recycling.

With this provision that clean water shall remain clean and shall be channelled off site towards a drainage line or public stream, without causing soil erosion, storm water shall be separated from the station terrace on basis of quality and cascaded to an appropriate destination or impoundment. An automatically operated sluice system should be set in place to separate storm water from the station terrace.

All dirty water must be retained on site in an impoundment designed according to the requirements as stipulated in Government Notice 704 (GN 704) and site specific environmental requirements. A suitable capillary breaker / liner should also be incorporated to safeguard ground water against pollution.

Storm water not conforming to the definition of clean or dirty water should be retained in a separate facility complete with infrastructure to allow for this water to cascade to the Ash System for the application as dust suppression or irrigation of rehabilitated areas. The station drains must be safeguarded against the ingress of coarse ash as a measure to ensure the integrity of the oil separation system.

There should also be a drainage system from all battery rooms which is coupled to the effluent sump at the water plant. All conveyer / transfer house wash water shall be collected and clarified through desilting prior to re-use in the ash conditioning system or cascading to the appropriate drain. Silt and wash water must be separated at the source and the design of the system shall allow for effective desilting of the facility.

Any area earmarked for future expansion of the power station must be isolated from the station drainage system to minimise dirty storm water yields.

3.1.3.5.11 Natural river sections and Open channels

There are many designs and lining methods for open channel sections. The SANRAL Drainage Manual: Chapter 4 illustrates and explains the full design for any shape of channel. To establish the lining type SANRAL Drainage Manual: Chapter 5 can be used in accordance with the following criteria:

1. Low Velocities - No Lining, Grass, Stone Pitching, Gabions, Reno-Mattresses, Concrete, Etc.
2. High Velocities - Concrete Lining With Energy Dissipaters
3. Clay Conditions - A Flexible Liner Such As Gabions, Interlocking Pre-Cast Concrete Slabs
4. Availability Of Materials
5. Cost
6. For Areas With A High Water Table, Permeable Linings Should Be Considered

As for sediment movement and deposition in channels SANRAL Drainage Manual: Chapter 8 can be utilised if all the sediment geological data is available.

3.1.3.5.12 Culverts

The SANRAL Drainage Manual: Chapter 7 will be used to design this structure.

3.1.4 Design Computations and Report

A design report shall be prepared containing the following information as a minimum:

1. The results of site investigations used for the design,
2. Geotechnical advice
3. Short outline of the design methods applied
4. All detailed calculation and results

All geotechnical computations shall be made using SI units. The calculation methods are not prescribed by this manual.

3.2 DESIGN STANDARDS FOR SEWERAGE DESIGN

3.2.1 Sanitary Sewer

As a rule provide separate collection systems to convey wastewater and stormwater.

Sewers are constructed to primarily transport wastewater from source to a point of treatment or ultimate disposal.

3.2.2 Typical Investigations

These include:

1. Physical
   - Topography, surface and subsurface conditions, paving or roads to be disturbed, underground services and structures, water table elevations, traffic control, etc.
   - Streets, obstructions, servitudes (horizontally and vertical features).
   - Existing sewer system to which the proposed sewer system will connect.
   - Future Extensions.
   - Service agreements with communities or Municipal entities.
2. Developmental
   - Population trends and densities.
   - Type of development (residential, commercial or industrial).
   - Existing master plans.
   - Future roads, airports, parks, industrial areas.
3. Political
   - Boundaries.
   - Municipal systems.
   - Agreements.
   - Regulations.
4. Sanitary
   - Quantity and strength of wastewater to be transported.
   - Water use statistics.
   - Flow measurements.
   - Capacity and condition of existing sewer system.
   - Infiltration/Inflow.
5. Economic studies

3.2.3 Geotechnical

A geotechnical investigation is generally required. Typically, the minimum investigation includes one (1) soil boring for each 500m of line and soil borings at significant structures such as pump stations and at stream crossings. Additional borings may be required at the discretion of the designer. .

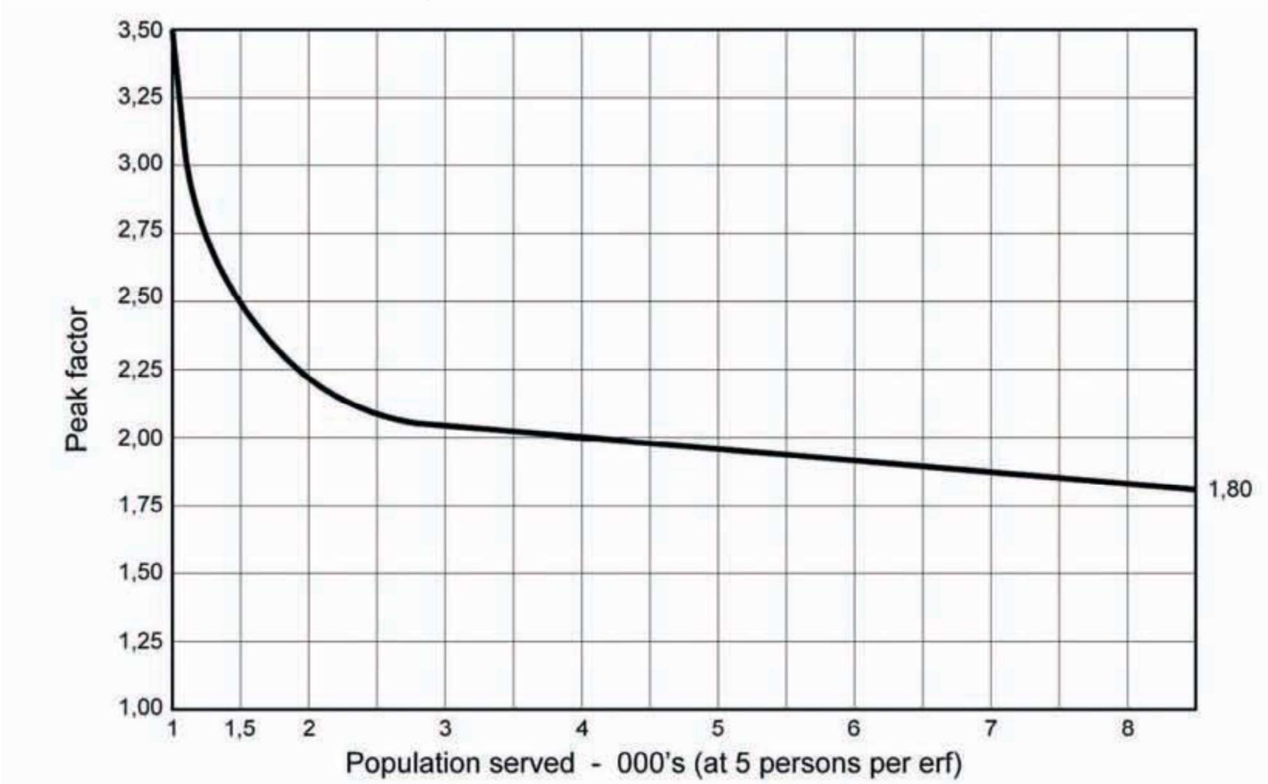
3.2.4 Design Period

- Typically 20 years for general sewers.
- Typically 50 years for sewer outfalls.

3.2.5 Design Flows

1. Design flows shall be based on the ultimate development using existing and/or projected land use for collector sewer of the size up to and including a nominal diameter of 600mm. See Appendix A.
2. Use actual measured flows as the basis for the design peak hourly flow rate whenever reliable wet and dry weather flow measurements are available.
3. In absence of actual measured flows, use average water use rates from comparable developments with an appropriate peaking factor and an allowance for infiltration and inflow as the basis for the design peak hourly flow rate.
4. Other criteria to be considered to determine the projected flow include:
   (a) Tributary areas.
   (b) Population estimate for the proposed development.
   (c) Land use.
   (d) Type of area (Residential, Commercial, Industrial).
   (e) Major point discharge (Incorporate major discharges from future point sources).
   (f) Ground water.
   (g) Infiltration and Inflow (Add to the design total flow).
   (h) Allowance for inflow for manholes in sag conditions.
5. Industrial sites (Such as on most Eskom sites) may vary significantly per industry, size and the way wastewater is being discharged. The Design Engineer shall determine the magnitude of the industries wastewater contribution in the area.
6. Addition of the individual flows for the design area gives the Average Daily Dry Weather Flow (ADDWF). Applicable design factors are applied depending on the land zoning.
7. The peak factor can be obtained from the following graph.

Figure 3.9 : Attenuation of peak flows



Source: "Red Book": Human Settlement Planning and Design, CSIR.

8. Additional to the ADDWF shall be allowed extra flows (infiltration, to give the Peak Daily Wet Flow (PDWF).

3.2.6 Pipe Flow

1. Pipes shall be of sufficient size to handle the total design flow, Q.
2. Main sewers and local collectors shall be designed with sewers flowing 2/3 full, d/D ≤ 2/3.
3. Sewer outfalls shall be designed with sewers flowing without surcharge, d/D ≤ 1.0.
4. Locations of sewer outfalls will be shown on Eskom or Local Authority's as-builts or master plans.
5. The minimum allowable internal diameter for any municipal sewer pipe is 200mm.
6. The flow in sewers may be calculated according to the Manning formula or Chezy equation, with n = 0.013.

   - Manning formula for flow velocity:

$$Q = \frac{A \times R^{2/3} \times S^{1/2}}{n} \qquad (9)$$

- Chezy equation:

$$Q = \frac{18log \times 12 \times R \times A\sqrt{RS}}{Ks} \qquad (10)$$

Where:

A= cross-sectional area of flow/conduit (m^2)

R = hydraulic radius of pipe (m)

S = gradient (m/m)

v = velocity of flow (m/s)

n= Manning's roughness coefficient

K_s= absolute roughness of conduit (m)

It is the designer's duty to use the appropriate Manning's roughness coefficient which depends on the pipe material used as well as its age. Use of other practical "n" values may be permitted by Eskom if deemed justifiable on the basis of research or field data submitted.

3.2.7 Minimum Slopes

All sewers should be designed to follow the general slope of the ground, provided that a minimum full bore velocity of 0.7m/s is maintained.

The following table can be used as a guideline. Table 3.12 indicates the minimum grades required to achieve this minimum full-bore velocity for various pipe sizes up to 300 mm in diameter.

Table 3.12 : Minimum Sewer Gradients

Minimum sewer gradients	
SEWER DIAMETER (MM)	MINIMUM GRADIENTS
100	1 : 120
150	1 : 200
200	1 : 300
225	1 : 350
250	1 : 400
300	1 : 500

Source: "Red Book": Human Settlement Planning and Design, CSIR.

1. The minimum pipe size for sewers in sewer reticulation shall be 100mm inside diameter.
2. Erf connections sewers shall have a minimum slope of 1:60. This gradient is required to clear the pipes at the head of the sewer network.
3. If a flatter slope is proposed, the pipe shall be designed to prevent settlement of solids in the pipe.
4. Where grades steeper than 1 in 10 are required, 15 MPa concrete anchor blocks should be provided that are at least 300 mm wide and embedded into the sides and bottom of the trench for at least 150 mm, as shown on Drawing LD-1 of SABS 1200 LD.

5. Steeper gradients may be necessary where the depth of flow is too low (d/D ≤ 20%).

3.2.8 Velocity

1. The flow velocity in sewers shall be kept between 0.7m/s and 2.0m/s.
2. The design flow shall not exceed 2m/s unless warranted by special conditions.

3.2.9 Servitude

Widths of servitudes must be sufficient to allow operations and maintenance activities within their boundaries. The minimum acceptable width for pipes not exceeding 200mm diameter is 2 metres. The width must be approved by Eskom or Local Authority. Adhere to way-leave requirements of all Authorities.

In all circumstances, temporary servitudes of greater width may be required to facilitate construction. All servitudes must be acquired before construction commences.

Trees may not be interfered with unless written permission is obtained from the relevant municipal official.

Provide separate collection systems to convey wastewater and storm water runoff.

Maintain a minimum horizontal distance of at least 3m between parallel and sanitary sewer lines. At points where sewers cross water mains, the sewer shall cross between the waterlines at an angle within 45°. If the distance between crossing pipes is less than 600mm, the designer must submit special requirements for consideration and approval by the Chief Engineer (DWH) at Eskom CoE.

Protection of gas, electric, telephone and other utility lines must be designed and installed in accordance with the relevant utility company's requirement.

3.2.10 Pipe Materials

The following pipes are acceptable for sewers:

1. uPVC Heavy Duty Class 34 to SANS 791 or solid (sandwiched) walled uPVC class 400 to SANS 1601 for sizes up to 400mm diameter.
2. HDPE sewer pipes for all sizes above 400mm diameter.
3. Where approved by Eskom, reinforced concrete pipes containing dolomitic aggregates can be used for sewers larger than 400mm. The pipes should have an approved sacrificial lining inside as per SANS 677.

The materials selected shall be suitable for local conditions, such as: septic conditions, soil characteristics, flow characteristics, and anticipated superimposed live and dead loads. Designers must obtain approval from the Eskom Chief Engineer (DWH) at the CoE.

Designs including a change in pipe material must transition between pipe materials at a manhole.

Only Polyethylene (PE) pipes shall be used in areas underlain by dolomite. Minimum allowable class PE

Pipe: PE80, PN6, SDR21.

Glass Fibre Reinforced Pipes (GFRP) may also be considered for use. This shall be at the Engineers discretion and the utilization of this material must be motivated, to the DWH CoE, prior to use.

The following design criteria should be considered when designing underground sewer lines:

- Pipe Loading Calculations
- Pipe Deflection Calculations

- Pipe Buckling Calculations
- Pipe Wall Crushing Calculations

3.2.11 Pipe Depth and Cover

Provide sewers at an adequate depth to accept waste water by gravity from the lowest floor of all contributing buildings.

The recommended minimum values of cover to the outside of the pipe barrel for sewers other than connecting sewers are as follows:

Table 3.13 : Minimum values of cover to the outside of the pipe barrel for sewers

Area	Minimum Cover (mm)
Trafficked areas	1400 (Below final road level)
In sidewalks	1400 below final kerb level
Other areas	1000

The designer must be certain that the combination of loading, pipe depth, pipe strength and bedding type will be satisfactory. Depths of cover for house connections must be such that the pipelines are not compromised by excess loading.

Where the recommended depth cannot be achieved a cast-in-situ or precast concrete slab(s) shall be over the pipe, isolated from the pipe crown by a soil cushion of 100 mm minimum thickness. The protecting slab(s) should be wide enough and designed so as to prevent excessive superimposed loads being transferred directly to the pipes.

Shoring of trenches is to the done in accordance with Occupational Health and Safety Act (85/1993): Construction Regulations, 2014.

Avoid sewer profiles in areas where the depth of cover over the top of pipe is fill material.

3.2.12 Flood Control

In the event that a proposed sewer is to cross a storm water channel, structure, or drainage course within the jurisdiction of the Agency (e.g. DWS), a detailed large-scale profile of the crossing shall be incorporated in the plans and submitted to the Agency for approval of the plans.

3.2.13 Manhole

Manholes must be installed at the end of each sewer, at all changes in sewer size, grade, or alignment and at all junctions. The maximum permitted manhole spacing for all sewers less than 1200 mm in diameter is 100 metres.

In general, manholes should provide convenient access to the sewer for observation and maintenance operations; should cause a minimum interference with the hydraulics of the sewer, should be durable structures and generally be watertight, and be strong to support applied loads.

For sewers crossing a road, there must be at least one manhole within the road reserve.

Manhole benching should have a grade not steeper than 1 in 5 nor flatter than 1 in 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 1.2d, where d is the nominal pipe diameter.

All manholes, including the connection between manhole and sewer, should be designed in accordance with the requirements of SANS 1200 LD.

All materials used for manholes should be in accordance with Section 3.5 of SANS 1200 LD.

Other general guidelines are as follows:

1. Manhole channels to be precast fibre cement even if uPVC pipes are used in reticulation
2. Manholes shall be precast concrete with dolomitic aggregate or fibre-cement rings (min. 1,05m nominal diameter).
3. Manholes must be coordinated to the applicable Lo27, Lo2 or Lo 31 (WGS84) and levels to be AMSL.
4. Step irons shall be Calcamite steel-plastic-coated or Copolymer Polypropylene, fixed to structures with suitable epoxy adhesive.
5. Benching in manholes shall be concrete of minimum strength of 20 MPa at 28 days.
6. Manholes deeper than 3 m shall be a minimum of 1.5 m in diameter.
7. Provide for sealing of manholes for water tightness with an approved sealant to prevent ingress of storm water.
8. With precast concrete sections joints must be caulked with a waterproofing compound and the outside of the joint wrapped with an approved sealing tape.
9. The flow channel through manholes shall be a smooth continuation of the pipe.
10. Provide a capped stub at the most upstream manholes for future extension to upstream of the service area.
11. Protect manholes from corrosion where corrosive conditions are anticipated by providing an approved protective coating.
12. Suitable manhole frame and cover to be provided.
13. Design should take into consideration differential settlement of the manhole and sewer in unstable soils as this may break the pipe.
14. Drop manholes should only be used with special permission from Eskom.
15. Gravity sewers shall be designed with straight alignment between manholes.

3.2.14 Sewer Connections

Where at all possible, house connections crossing a road must be avoided.

All connections shall be a minimum of 110mm internal diameter. Erf connections must be provided from the main sewer to a distance of 0.5 m inside the erf boundary.

Direct connections to 160mm pipes will be allowed in residential areas, but industrial connections will only be allowed into a manhole on the sewer main. An inspection chamber must be constructed on the property boundary for commercial park developments in front of the manhole where the connection is made. Connections to sewers of more than 160 mm diameter are only allowed through manholes.

Each erf must be provided with a sewer connection of sufficient depth to drain the full area on which building construction is allowed, with a minimum of 80% of the total erf area. The minimum depth to the invert of a sewer connection is 1.50m in a road reserve and 1.2 m in a mid-block.

At a junction with the main sewer, a plain 45º junction should be used at the point where the connecting sewer joins the main sewer. Saddles should not be permitted during initial construction.

Typical Connection details see Appendix B, and depth calculations are available on the Tshwane website.

3.2.15 Bedding and Backfilling

SANS 1200DB and SANS 1200LB to be used for trench excavation, bedding and backfill. Usually, these requirements are adequate. Where special conditions warrant, additional details may be shown on the project plans, or the Special Provisions may include such special requirements.

1. All bedding material must be of selected granular material with a PI less than 6, and free from organic matter, clay or stones larger than 20mm.
2. Subsoil drains are to be provided where ground water is a problem. The designer shall ensure that the design is sufficient to meet the requirements.
3. Backfill material must be homogeneous and must be compacted in 150mm layers to 93% Modified AASHTO density.
4. Density tests must be carried out on the backfill.
5. The trenches must be dewatered during construction.
6. The applicable SANS standards must be adhered to (1200DB, 1200LB, 1200L, 1200LD, etc.).

3.2.16 Dewatering of Trench

Where water is encountered in the trench, it shall be removed before pipe-laying operations and the trench so maintained until the ends of the pipe are sealed and provisions are made to prevent floating of the pipe. Trench water or other deleterious materials shall not be allowed to enter the pipe at any time. Dewatering is required to 300mm below the invert of the pipe.

The contractor shall furnish, install, and operate all necessary dewatering wells and equipment to keep the trench free from water during construction, and shall dewater and dispose of the water so as not to cause injury to public or private property or nuisance to the public. Sufficient pumping equipment in good working condition shall be available at all times for all emergencies, including power outage, and shall have available at all times competent workers for the operation of the pumping equipment.

3.2.17 Permits

Permits are required for all sewer work, including but not limited to the following:

1. Private construction of public infrastructure
2. Excavation
3. Street Obstruction
4. Traffic control
5. Other as necessary

3.2.18 Sewers above Ground

It may be required to build sewers above ground surface or across gullies and stream valleys. These may be using pipe bridges, support on concrete piers, etc. Design calculations must be submitted to the DWH CoE for verification. Foundations should be adequately sized to prevent overturning and settlement. Expansion joints may be required.

Cast or ductile iron pipe or steel pipes are used [19]. Provide special couplings to avoid leakage. Use adequate linings and coatings for corrosion protection.

The impact of flood waters and debris should be considered.

3.2.19 Sewers in Areas Underlain by Dolomite

Designers are advised to consult the following publications regarding work in dolomitic areas:

1. Proposed method for dolomite land hazard and risk assessment in South Africa, SAICE Journal Volume 43(2) 2001, paper 462 pages 27-36, Buttrick et. al. (Current industry standard document).
2. Section 2.8 of Part 1 of the Home Building Manual as published by the NHBRC, Revision 1, 1999.

3. PW344: "Appropriate Development Infrastructure on Dolomite: Manual for Consultants" as published by the National Department of Public Works, June 2006. This document is available under Consultants Documents on the website of the Department of Public Works (www.publicworks.gov.za).

All work on dolomitic land is subject to the approval of the Eskom Chief Engineer (DWH) at the CoE.

The minimum requirements for the upgrading, extension and development of new infrastructure on dolomite are as set out in the PW344 document referred to above.

3.2.20 Sewer Testing and Inspection

Testing shall be accomplished through the combination of visual inspections, deflection tests, low-pressure air tests, and leakage tests methods. Acceptance tests shall only be performed after all work adjacent to and over the pipeline has been completed. Backfilling, placement of fill, grading, initial/base layer of paving, concrete work, and any other superimposed loads shall be completed and in place prior to any testing. All testing shall be performed in the presence of the Eskom's representative, after the installation of all other utilities (including power poles). Tests performed in the absence of the Eskom's representative shall be considered invalid and shall be repeated at the Contractor's expense.

The tests include:

1. Inspection on completion of the excavation prior to laying the pipe to verify alignment and ensure the pipe is free from obstructions and debris.
2. Inspection of prescribed bedding and the compaction of surrounding material up to the centreline level of the pipe.
3. Air or water tests, as prescribed in the standard specification SANS 1200, are to be conducted after the placing and compaction of the backfilling. Contractors must pressure test the pipeline prior to backfilling, at their own expense, to avoid excavation of the final backfill
4. Density tests must be conducted on bedding and backfill material in accordance with the project specifications.
5. Inspection of the construction of the manholes and completion of the backfill
6. CCTV inspections are to be conducted on all sections of the pipe. The CCTV video and reports are to be submitted as part of the as-built information.
7. A percolation test, as prescribed in the project specifications, must be conducted on sites where septic tanks and French drain systems are to be installed.
8. A drop test in accordance with BS 8007 may be called for manholes to ensure that they are water-tight.
9. Hydrostatic pressure test for pressure lines.
10. Adhere to the latest published Construction Regulations, OHS act, etc.

3.2.21 On-Site Treatment of Wastewater

There is currently no Eskom standard for on-site treatment of wastewater. The following guidelines can be referred to and used by the designer.

1. Code of Practice for the Application of National Building Regulations (NBR), SABS 0400-1990 and Building Standards Act No.103 of 1977 or latest revisions thereof.
2. Local authority guidelines.
3. Ethekwini Water And Sanitation Unit Policy For The Installation Of Privately Owned Low Volume Domestic Sewage Treatment Systems

3.2.22 Sewage Pump Station and Pumping Mains Design Guidelines

An Eskom pump station design standard is yet to be developed. This is specialised standard and Eskom's Low Pressure Services (LPS) department must be consulted at all times during the design and implementation stage of the project.

The City of Tshwane has on their website a section which gives guidelines for the design of sewage pump stations.

3.2.23 Conservancy tanks and septic tanks

In the instance that there is no existing sewage infrastructure in place, on a specific site, it may be necessary for the Engineer to design a conservancy tank or septic tank. This design is to be done in accordance with SANS 10400 – P: Drainage. This design will need to be sent to the DWH CoE for verification.

3.2.24 Pipeline Hydraulic Calculations

Sewer Main hydraulic capacity calculations shall be presented in tabular form and shall include the following information for each reach of sewer:

1. Terminal manhole designation
2. Ground elevations at terminal manholes
3. Incremental and cumulative tributary areas
4. Incremental and cumulative tributary population
5. Incremental average and maximum domestic sewage flow
6. Incremental infiltration/inflow allowance
7. Basis for Peak Wet Weather allowance
8. Cumulative design flow
9. Invert and rim elevations of manholes
10. Length of sewer run
11. Sewer pipe size and slope

4. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation
Gareth Macintosh	Acting Discipline Manager: Dams, Waterways and Hydro Design Engineering
Funeka Grootboom	Chief Engineer: Dams, Waterways and Hydro Design Engineering
Samuel Ramsamy	Engineer: Dams, Waterways and Hydro Design Engineering
Morne Van Heerden	Engineer: Dams, Waterways and Hydro Design Engineering

5. REVISIONS

Date	Rev.	Compilers	Remarks
October 2014	0.1	S Ramsamy / M J van Heerden	Draft Document for review created
October 2014	0.2	S Ramsamy / M J van Heerden	Draft Document for Comments Review (Internal)
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March 2018	1.3	S Ramsamy / M J van Heerden	Final Document for Authorisation and Publication
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6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Samuel Ramsamy
- Morne J van Heerden
- Funeka Grootboom

7. ACKNOWLEDGEMENTS

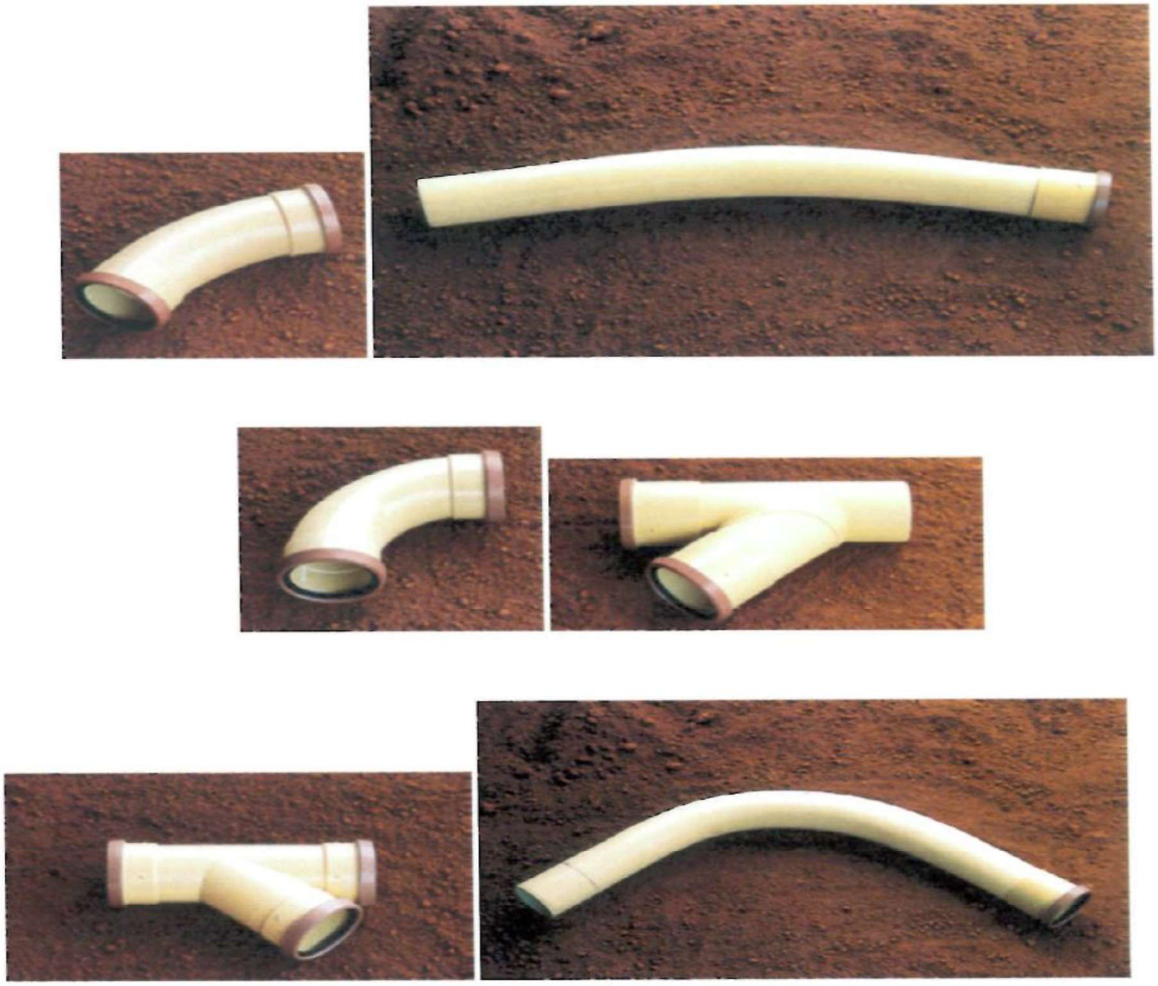
- None

APPENDIX A: GUIDELINE FOR SEWER FLOW CALCULATIONS (TSWANE 18TH FEB 2008)

ITEM	ZONING	MEASURING UNIT/DAY	SEWAGE OUTFLOW PER DAY
1	**RESIDENTIAL:**		
1.1a	Low-cost housing – erf up to 250 m²	kℓ per erf	0.6
1.1b	Small sized erven, for typically "Bonded Housing" etc.	kℓ per erf	0.6
1.2	Conventional small-sized erf up to 500 m²	kℓ per erf	0.7
1.3	Medium-sized erf 501m² up to 1 000 m²	kℓ per erf	0.8
1.4	Large-sized erf 1 001m² up to 1 500 m²	kℓ per erf	0.8
1.5	Extra-large erf 1 501 m² and larger	kℓ per erf	0.8
1.6	Cluster housing up to 20 units per hectare	kℓ per unit	0.7
1.7	Cluster housing 21 up to 40 units per hectare	kℓ per unit	0.6
1.8	Cluster housing 41 up to 60 units per hectare	kℓ per unit	0.6
1.9	High-rise flats (± 50 m² per unit) + FSR residential	kℓ per unit/50m²	0.6
1.10	Boarding houses, hostel, hotel, retirement centres and villages, orphanages, etc. according to FSR	kℓ per 100m²	0.9
1.11	Agricultural holdings (house + servants quarters + garden) (to be used only for subdivisions to create multiple holding)	kℓ per holding	1.4
1.12	Guesthouses - allocation per room regardless of room size	kℓ per room	0.6
1.13	Gate house for security villages	kℓ per unit	0.6
2	**BUSINESS DEVELOPMENTS:**		
2.1	General business with a FSR	kℓ per 100m²	0.8
2.2	Warehousing (including up to 20% offices)	kℓ per 100m²	0.4
2.3	Industrial (dry)	kℓ per 100m²	0.3
2.4	Industrial (wet)	kℓ per 100m²	Development specific
2.5	Garage or filling station	kℓ per 100m²	1.0

ITEM	ZONING	MEASURING UNIT/DAY	SEWAGE OUTFLOW PER DAY
2.6	Car wash facility	kℓ per wash bay	0.1
2.7	Motor city / retail park as a single zoning (car sales + limited offices)	kℓ per $100m^2$	0.4
3	**GENERAL TYPE OF DEVELOPMENT:**		
3.1a	Club building	kℓ per $100m^2$	0.3
3.1b	Club grounds	kℓ per hectare	0
3.2a	Stadium	kℓ per 1000 people	1.5
3.2b	Stadium grounds	kℓ per hectare	0
3.3a	Park buildings	kℓ per $100m^2$	0.4
3.3b	Park grounds	kℓ per hectare	0
3.4a	Nursery (sales area)	kℓ per $100m^2$	0.8
3.4b	Nursery (planting and production area)	kℓ per hectare	0
3.5a	Hospital buildings	kℓ per $100m^2$	1.2
3.5b	Hospital grounds	kℓ per hectare	0
3.6a	Church buildings	kℓ per $100m^2$	0.3
3.6b	Church grounds	kℓ per hectare	0
3.7a	School, crèche, educational building	kℓ per $100m^2$	0.6
3.7b	School, crèche, educational grounds	kℓ per hectare	0
3.8	Municipal, governmental developments	kℓ per $100m^2$	0.6
3.9	Private open space	kℓ per hectare	0
3.10	Parking grounds	kℓ per hectare	0

APPENDIX B: TYPICAL SEWER CONNECTIONS/FITTINGS



Some typical fitting used in making connections