



BSI Standards Publication

Drain and sewer systems outside buildings - Design

Part 2: Hydraulic design

National foreword

This British Standard is the UK implementation of EN 16933-2:2017.

The UK participation in its preparation was entrusted to Technical Committee B/505/22.

The UK committee draws users' attention to the National Annex NA, which provides further guidance to assist users in the application of BS EN 16933-2:2017.

A list of organizations represented on this committee can be obtained on request to its secretary.

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30 June 2018	Addition of a National Annex
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English Version

Drain and sewer systems outside buildings - Design - Part 2: Hydraulic design

Réseaux d'évacuation et d'assainissement à l'extérieur
des bâtiments - Conception - Partie 2 : Conception
hydraulique

Entwässerungssysteme außerhalb von Gebäuden -
Planung - Teil 2: Hydraulische Planung

This European Standard was approved by CEN on 30 July 2017.

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European foreword

This document (EN 16933-2:2017) has been prepared by Technical Committee CEN/TC 165 “Wastewater engineering”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2018 and conflicting national standards shall be withdrawn at the latest by March 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This European Standard EN 16933, *Drain and sewer systems outside buildings — Design*, contains the following parts:

- Part 1: Physical design¹⁾
- Part 2: Hydraulic design.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

¹⁾ Currently in preparation.

Introduction

Drain and sewer systems are part of the overall wastewater system that provides a service to the community. This can be briefly described as:

- removal of wastewater from premises for public health and hygienic reasons;
- prevention of flooding in urbanised areas;
- protection of the environment.

The overall wastewater system has four successive functions:

- collection;
- transport;
- treatment;
- discharge.

Collection and transport of wastewater is provided by drain and sewer systems.

EN 752:2017 provides a framework for the design, construction, maintenance, operation and rehabilitation of drain and sewer systems outside buildings. This is illustrated in the upper part of the diagram in Figure 1. EN 752:2017 is supported by more detailed standards for the investigation, design, construction, organization and control of drain and sewer systems.

Investigation and assessment standards include:

- EN 13508, *Investigation and assessment of drain and sewer systems outside buildings*.

Design and construction standards include:

- EN 16932²⁾, *Drain and sewer systems outside buildings — Pumping systems*;
- EN 16933³⁾, *Drain and sewer systems outside buildings — Design*;
- EN 1295⁴⁾, *Structural design of buried pipelines under various conditions of loading*;
- EN 1610, *Construction and testing of drains and sewers*;
- EN 12889, *Trenchless construction and testing of drains and sewers*;
- EN 15885, *Classification and characteristics of techniques for renovation, repair and replacement of drains and sewers*.

Management and control standards include:

- EN 14654, *Management and control of operational activities in drain and sewer systems outside buildings*.

²⁾ Currently in preparation.

³⁾ Currently in preparation.

⁴⁾ Currently in preparation.

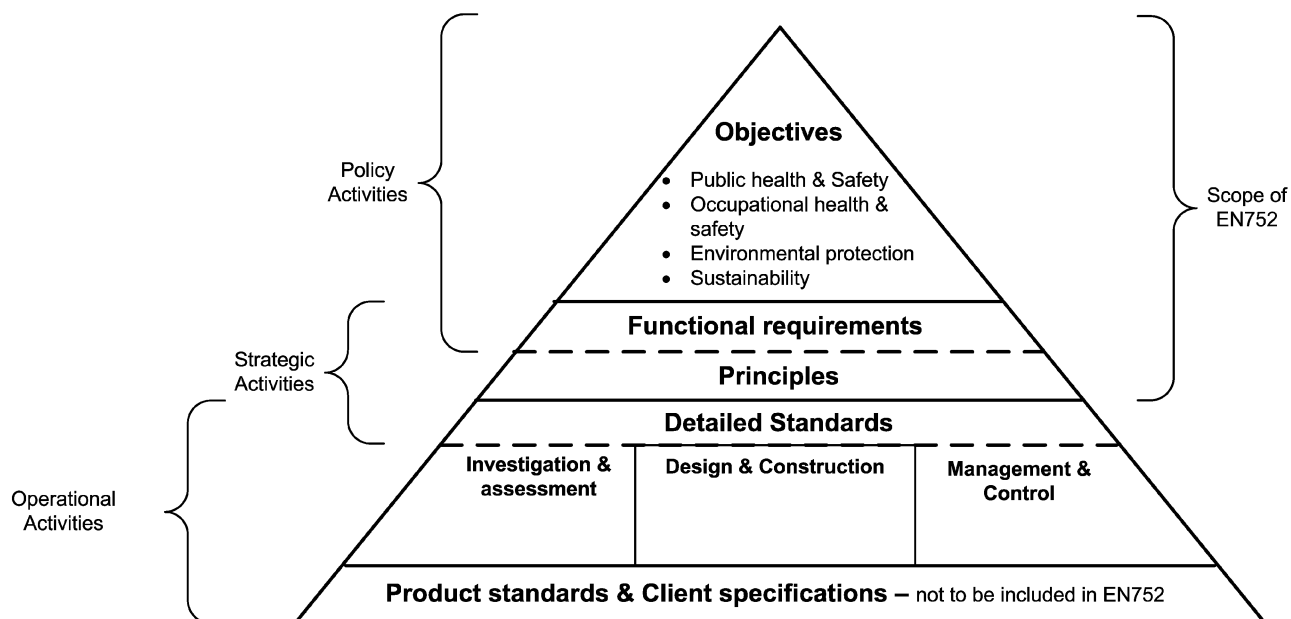


Figure 1 — Relationship to EN 752:2017 and other drain and sewer standards [Source EN 752:2017]

1 Scope

This European Standard specifies requirements for the design of drain and sewer systems outside buildings.

It is applicable to drain and sewer systems from the point where the wastewater leaves a building, roof drainage system, or paved area, to a point where it is discharged into a wastewater treatment plant or receiving water body.

This document specifies requirements for the hydraulic design of drain and sewer systems and the assessment of the capacity of existing drain and sewer systems.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 858-1, *Separator systems for light liquids (e.g. oil and petrol) — Part 1: Principles of product design, performance and testing, marking and quality control*

EN 858-2:2003, *Separator systems for light liquids (e.g. oil and petrol) — Part 2: Selection of nominal size, installation, operation and maintenance*

EN 1825-1, *Grease separators — Part 1: Principles of design, performance and testing, marking and quality control*

EN 1825-2:2002, *Grease separators — Part 2: Selection of nominal size, installation, operation and maintenance*

EN 16323:2014, *Glossary of wastewater engineering terms*

EN 752, *Drain and sewer systems outside buildings — Sewer system management*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 16323, EN 752 and the following apply.

NOTE 1 Certain key definitions from EN 16323:2014 have been repeated below for clarity. The following additional terms used in this document are defined in EN 16323:

backdrop manhole;	catchment area;	combined sewer overflow;
combined system;	detention tank;	domestic wastewater;
drain;	dry weather flow;	extraneous flow;
foul wastewater;	gradient;	gravity system;
hydro-biological stress;	industrial wastewater;	infiltration (see Figure 2);
inspection chamber;	inverted syphon;	maintenance;
manhole;	outfall;	ramp manhole;
receiving water body;	rehabilitation;	relevant authority;
renovation;	repair;	replacement;
rising main;	runoff coefficient;	self-cleansing;
self-purifying capacity;	separate system;	septic wastewater;

sewer; sewer system;
time of concentration;

surcharge;
time of flow;

tank sewer;
wastewater treatment plant.

NOTE 2 The following additional terms used in this document are defined in EN 752:2017:

expected frequency

flooding

rainfall intensity

3.1

depression storage

precipitation retained in surface hollows that does not contribute to runoff

3.2

rainwater

water arising from atmospheric precipitation, which has not yet collected matter from the surface

Note 1 to entry: See Figure 2.

[SOURCE: EN 16323:2014, 2.1.1.1]

3.3

runoff

water from precipitation that flows off a surface to reach a drain, sewer or receiving water

Note 1 to entry: See Figure 2.

[SOURCE: EN 16323:2014, 2.1.1.2]

3.4

sub-critical flow

state of flow when the water velocity is less than the velocity of the small surface wave with water levels tending to be stable

3.5

super-critical flow

state of flow when the water velocity is greater than the velocity of the small surface wave with violent fluctuations in water level being possible

3.6

surface receiving water body

receiving water body that is on the surface of the ground (e.g. river, lake or sea)

Note 1 to entry: See Figure 2.

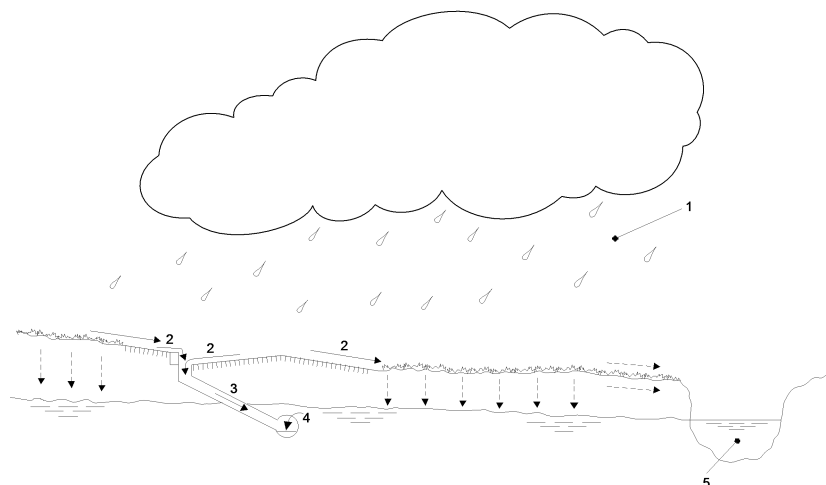
[SOURCE: EN 16323:2014, 2.1.3.7]

3.7

surface water

water from precipitation, which has not seeped into the ground and is discharged to the drain or sewer system directly from the ground or from exterior building surfaces (see Figure 2)

[SOURCE: EN 16323:2014, 2.1.1.3]



Key

- 1 rain water
- 2 runoff
- 3 surface water
- 4 infiltration
- 5 surface receiving water body

Figure 2 — Terminology for flows derived from rain water [Source EN 16323:2014]

3.8
vortex manhole
 circular manhole within which a large difference in level is accommodated by the wastewater entering tangentially and descending helically

3.9
wastewater
 water composed of any combination of water discharged from domestic, industrial or commercial premises, surface run-off and accidentally any sewer infiltration water

[SOURCE: EN 16323:2014, 2.3.10.65]

4 Symbols and units

For the purposes of this document, the following symbols and units apply.

- A_c is the area receiving rainfall (measured horizontally), in hectares [ha]
- A_f is the flow cross-section perpendicular to the invert of the drain or sewer, in metres squared [m^2]
- C_s is the runoff coefficient (between 0,0 and 1,0), dimensionless [-]
- c is the factor with inclusion of additional losses, dimensionless [-]
- D is the internal diameter of the pipe (bore), in metres [m]
- g is the acceleration due to gravity, in metres per second squared [m/s^2]
- h_f is the local headloss in bends, valves and other fittings, in metres [m]

h_p	the pipeline head loss due to friction, in the pipe in metres [m]
i	is the rainfall intensity, in litres per second and hectare [l/s/ha]
J_E	is the hydraulic gradient (energy loss per unit length), dimensionless [-]
J_F	is the friction gradient, dimensionless [-]
J_S	is the gradient of the invert of the drain or sewer (with open channel possibly not constant), dimensionless [-]
K	is the Manning coefficient, in metres raised to the power one third per second [$m^{1/3}/s$]
k_f	is the headloss coefficient, dimensionless [-]
k_s	is the hydraulic pipeline roughness, in metres [m]
L	Is the length of the pipeline, in metres [m]
Q	is the flow, in metres raised to the power of three per second [m^3/s]
Q_{pk}	is the peak flow rate, in litres per second [l/s]
q	is the lateral inflow per unit of length in the direction of the flow (assumed steady-state), in metres cubed per second and metre [$m^3/(s\ m)$]
R_h	is the hydraulic radius, in metres [m]
t	is the time coordinate, in seconds [s]
v	is the velocity in the direction of flow averaged across the flow cross-section, in metres per second [m/s]
x	is the path coordinate in direction of flow, in metres [m]
y	is filling height in profile or depth of water (perpendicular to invert) or the pressure head in completely filled drains at the invert of the pipe or profile, in metres [m]
λ	is the friction coefficient for the pipe, dimensionless [-]
ν_k	is the kinematic viscosity of fluid, in metres squared per second [m^2/s]

5 General

EN 752 specifies objectives and functional requirements and the principles for design of drain and sewer systems outside buildings.

Hydraulic design can affect the functional requirements, in particular the following:

- protection from sewer flooding;
- protection of surface receiving water bodies;
- prevention of odours and toxic, explosive and corrosive gases;
- maintaining the flow.

Drains and sewers systems shall be designed to provide sufficient capacity for the design flows. In selecting the diameter and/or gradient of the pipe consideration shall also be taken of the need to minimize build-up of sediments and to minimize the risk of blockages (see 7.1).

6 Design criteria

Except where they are specified by national or local regulations or the relevant authority, design criteria shall be determined in accordance with EN 752:2017, 5.3.2.

Design criteria relating to hydraulic design can include:

- a) the expected frequency at which no surcharge occurs in the drain and sewer system;
- b) the expected frequency at which a specified amount of surcharge occurs in the drain and sewers system;
- c) the expected frequency of sewer or surface water flooding (this can occur without surcharge);
- d) the impact of the flows from surface water outfalls on river flooding from surface receiving water bodies or on groundwater flooding; and
- e) the impact of flows on the operation of the wastewater treatment plant.

7 Hydraulic capacity of pipelines

7.1 Introduction

The basis for design is that flows in drains and sewers are turbulent. Two formulae are recommended for use in calculating turbulent flows in drains and sewers: Colebrook-White⁵⁾ and Manning⁶⁾.

7.2 Pipeline headlosses

7.2.1 General

When using recommended hydraulic pipeline roughness values it is necessary to establish whether allowance has been included for local headlosses. The hydraulic pipeline roughness (k_s) or the Manning flow coefficient (K) should allow for headlosses due to pipe material taking account of other factors including, the internal profile of the pipe, losses due to discontinuities at the joints and biofilms that grow on the pipe surface below the water level.

The effect of the biofilm can be more significant than any difference in the roughness of the material without the biofilm. A single value, regardless of pipe material is therefore often used.

7.2.2 The Colebrook-White formula

For circular pipes flowing full, the velocity of flow is given by Formula (1):

$$v = -2 \cdot \sqrt{(2 \cdot g \cdot D \cdot J_E)} \cdot \log_{10} \left(\frac{k_s}{3,71 \cdot D} + \frac{2,51 \cdot \nu_k}{D \cdot \sqrt{(2 \cdot g \cdot D \cdot J_E)}} \right) \quad (1)$$

For partially running full pipes or pipes with non-circular cross-sections the velocity of flow is given by Formula (1) by replacing D by $4 R_h$ where R_h is the hydraulic radius (flow cross-sectional area divided by the wetted perimeter).

⁵⁾ This formula is named Colebrook in the French version and Prandtl-Colebrook in the German version.

⁶⁾ This formula is named Manning-Strickler in the French and German versions.

7.2.3 The Manning formula

For both circular and non-circular cross-sections whether running full or partially full, the velocity of flow is given by the Formula (2):

$$v = KR_h^{2/3} J_E^{1/2} \quad (2)$$

7.2.4 Pipeline roughness values

When using recommended hydraulic pipeline roughness values it is necessary to establish whether allowance has been included for local headlosses. Values currently in use differ from country to country, and range from 0,1 mm to 3,0 mm for k_s and $70 \text{ m}^{1/3} \text{ s}^{-1}$ to $90 \text{ m}^{1/3} \text{ s}^{-1}$ for K .

Approximate comparisons of velocity estimates using Formulae (1) and (2) above can be made using the following Formula (3):

$$K = 4 \cdot \sqrt{g \cdot \left(\frac{32}{D}\right)^{1/6}} \cdot \log_{10} \left(\frac{3,71 \cdot D}{k_s} \right) \quad (3)$$

7.2.5 Pipeline headloss values

To calculate the head loss in the pipe for given flow conditions, the friction coefficient can be calculated from Formula (4):

$$\lambda = \frac{2 \cdot g \cdot D \cdot J_E}{v^2} \quad (4)$$

The pipeline headloss in the pipe can then be calculated from Formula (5):

$$h_p = \frac{\lambda \cdot L}{D} \quad (5)$$

7.3 Local headlosses

Headlosses, in addition to those mentioned in 7.2, occur at junctions, changes of cross-section, manholes, bends and other fittings. If direct calculations are to be made, the following Formula (6) shall be used:

$$h_f = \frac{k_f \cdot v^2}{2 \cdot g} \quad (6)$$

7.4 Total headlosses

Two methods of calculating total headlosses are:

- adding local headlosses (see 7.3) to the pipeline headlosses (see 7.2);
- accounting for local headlosses by assuming a higher value of hydraulic pipeline roughness in the calculation of pipeline headloss.

8 Incoming flows

8.1 Foul wastewater flows

8.1.1 General

For drains and sewers serving small populations, the capacity of the pipe is often determined by the minimum pipe diameter specified by the relevant authority.

In gravity drains and sewers the ratio between the peak flow and the average dry weather flow reduces as the flow moves downstream.

Where the flow passes through the collection tank of a pumping system, attenuation occurs and the ratio between the peak flow and the average dry weather flow used to design the pumps is reduced accordingly. The peak flow downstream of the pumping station is determined by the capacity of the pumps.

8.1.2 Calculation of foul wastewater flow rates based on the appliances connected

The design of drains and sewers to serve individual or groups of buildings where discharges from individual appliances give relatively high flows of an intermittent and irregular nature shall use a peak rate of flow derived from the number and type of appliances connected.

The rates of flow in the drains from the buildings or premises, calculated using EN 12056-2, should be used in the design of downstream drain systems.

Flow rates for individual appliances and factors to be applied can be specified by national or local regulations or the relevant authority. Industrial wastewater flows shall be calculated separately.

This method may be used for the design of gravity foul drains and sewers where the upstream population is less than approximately 1 000.

8.1.3 Calculation of foul wastewater flow rates from population and average flows

Where the dry weather flow is continuous and large enough that it is not significantly increased by the input from single appliances, the design foul wastewater flow rates for domestic wastewater can be calculated as follows. Flow rates can be based on either: the population and a measured rate of flow per head or, for new developments where such data are not available, on the planning criteria for the population or the type and number of dwellings. For a new development and for an upgrading scheme on an existing development, the estimates used shall be appropriate for the specified planning horizon.

This method may be used for the design of gravity foul drains and sewers where the upstream population is greater than approximately 500.

Existing water supply statistics can be helpful to derive future water supply consumption and hence domestic wastewater flows. Flow patterns for daily consumption and anticipated variations between different types of development can also be established. Consumer water usage that does not enter the drain and sewer system and distribution leakage are of particular importance in assessing domestic wastewater flows. The rate of flow per head can be based on local water supply statistics allowing for consumption that does not result in discharge to the sewers and, where appropriate meters are not available, distribution losses. Typical discharge figures for developments similar to those under consideration may also be used.

The peak design foul wastewater flow rate shall take into account the ratio between the peak foul wastewater flow rate and the average value. For existing systems, where there is continuous flow this should be based on measured values where these are available. Where measured values are not available design peak flow factors should be estimated by comparison with similar catchments.

Design values for the peak factor or the peak flow rates can be specified in national documents.

8.2 Rainfall and runoff from precipitation

8.2.1 Rainfall

National or local regulations or the relevant authority can specify design rainfall values to be used. Design rainfall intensities reflecting the local conditions can be in one of the following forms:

- a) local or regional constant rate rainfall values;
- b) constant rate rainfall calculated from intensity-duration-frequency curves;
- c) single event rainfall profiles;
- d) rainfall time series.

Single even rainfall events or rainfall time series can either be taken from observed historic rainfall data, or be formed from artificial profiles based on statistical analysis of rainfall data.

8.2.2 Runoff

8.2.2.1 General

Runoff shall be calculated taking into account a number of factors including:

- a) design rainfall;
- b) area that could drain to the inlets connected to the system:
 - 1) extent of impermeable area;
 - 2) extent of permeable area;
- c) likely losses of runoff due to:
 - 1) infiltration of rainfall into the ground;
 - 2) interception, i.e. rainfall retained by vegetation or other objects that prevents raindrops falling onto the ground;
- d) likely above ground flows from adjacent pervious surfaces;
- e) likely increases in connected area.

The possible impact of climate change should also be considered.

A simple method of calculating the runoff from small areas is included in 8.2.2.2.

8.2.2.2 Methods of calculating runoff from small development schemes

In the absence of a method specified by national or local regulations or the relevant authority, a simple method of estimating the peak rate of discharge of surface water, applicable for areas of up to 200 ha or times of concentration up to 15 min and assuming a uniform rate of rainfall intensity, may be used. The rainfall intensity to be adopted depends on factors such as time of concentration of the contributing area and the analysis of local rainfall data. Peak flow rate is given by Formula (7):

$$Q_{pk} = C_s \cdot i \cdot A_c \quad (7)$$

Appropriate values for (C_s) are given in the Table 1.

Table 1 — Runoff coefficients for calculating runoff from small development schemes

Nature of connected area	Runoff Coefficient C_s	Comments
Impermeable areas and steeply sloping roofs ^a	0,9 to 1,0	Depending on depression storage
Large flat roofs	0,7 to 1,0 ^b	Over 10 000 m ²
Small flat roofs	1,0	Less than 100 m ²
Permeable areas	0,0 to 0,3	Depending on ground slope and cover
^a Vertical surfaces should be considered as appropriate. ^b Depending on type of roof material (gravel at low end glass or metal at top).		

8.2.2.3 More complex runoff models

Where sewer flow simulation models are being used consideration should be given to other factors that can affect the runoff. These include:

- a) the movement of rainwater from paved areas to adjacent permeable areas;
- b) the infiltration of rainwater through cracks or impermeable areas in paved surfaces;
- c) the storage of rainwater in depressions in the surfaces;
- d) the evaporation of rainwater from surfaces;
- e) the movement of runoff from permeable surfaces onto paved surfaces, for example when:
 - 1) the rate of rainfall exceeds the infiltration capacity of the permeable surface;
 - 2) the soil is so saturated that rainwater cannot infiltrate into the ground;
 - 3) the soil has become frozen; or
 - 4) the soil has become temporarily impermeable due to a long period of hot and dry weather.

Various runoff models are included in available sewer flow modelling software to model these processes.

8.3 Extraneous flows

If the risk of extraneous water entering drains and sewers is considered to be unacceptable, investigations shall be carried out to determine the extent of this risk. Sources of extraneous flow can include:

- misconnections of surface water to foul drains and sewers;
- seepage of runoff through joints in manhole covers;
- infiltration of water from the ground through defective joints or other defects in drains and sewers and other associated structures (e.g. manholes and inspection chambers).

An allowance for extraneous flows may be made by increasing the design dry weather flows (see 8.1). When estimating likely extraneous flows account should be taken of local factors including:

- the groundwater levels;
- the standards of construction including the amount of supervision and control of drain and sewer construction.

9 Hydraulic calculation of drain and sewer systems

9.1 General

A variety of methods have been developed to assist in the design of drain and sewer systems. In all cases the runoff process has been simplified to enable the design parameters to be estimated cost effectively. This document reviews the range of methods available and gives guidance where they should be used.

9.2 Flow in sewer systems

Flow in drain and sewer systems is unsteady gradually varied flow. The flow conditions can be calculated by application of the Saint Venant formulae. These partial differential formulae describe the gradually varied unsteady, non-uniform flow in open and closed channels. There are two formulae; the dynamic formula, and the continuity formula. Depending on the application and the flow conditions different levels of simplification may be applied. These formulae are shown in Table 2 at various levels of simplification.

Table 2 — The Saint Venant formulae

Type of flow	Dynamic formula					No.	Continuity formula	No.
gradually varied non-uniform discontinuous (i.e. with lateral inflow)	$\frac{cvq}{gA_f} +$	$\frac{1}{g} \times \frac{\delta v}{\delta t} +$	$\frac{v}{g} \times \frac{\delta v}{\delta x} +$	$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8a)	$\frac{\delta Q}{\delta x} + \frac{\delta A_f}{\delta t} = q$	(9a)
gradually varied non-uniform		$\frac{1}{g} \times \frac{\delta v}{\delta t} +$	$\frac{v}{g} \times \frac{\delta v}{\delta x} +$	$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8b)	$\frac{\delta Q}{\delta x} + \frac{\delta A_f}{\delta t} = 0$	(9b)
gradually varied simplified non-uniform		$\frac{1}{g} \times \frac{\delta v}{\delta t} +$		$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8c)	$\frac{\delta Q}{\delta x} + \frac{\delta A_f}{\delta t} = 0$	(9b)
simplified gradually varied non-uniform			$\frac{v}{g} \times \frac{\delta v}{\delta x} +$	$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8d)	$\frac{\delta Q}{\delta x} + \frac{\delta A_f}{\delta t} = 0$	(8b)
simplified gradually varied simplified non-uniform				$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8e)	$\frac{\delta Q}{\delta x} + \frac{\delta A_f}{\delta t} = 0$	(9b)
steady-state non-uniform			$\frac{v}{g} \times \frac{\delta v}{\delta x} +$	$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8d)	$\frac{\delta Q}{\delta x} = 0$	(9c)
steady-state simplified non-uniform				$\frac{\delta y}{\delta x} =$	$J_S - J_F$	(8e)	$\frac{\delta Q}{\delta x} = 0$	(9c)
steady-state uniform (normal discharge)				$\frac{\delta y}{\delta x} =$	0	(8f)	$\frac{\delta Q}{\delta x} = 0$	(9c)
Term ref (see below)	5	4	3	2	1	–	–	–

NOTE For most practical purposes the friction gradient (J_F) can be considered as equal to the hydraulic gradient (J_E).

The different terms in the dynamic formula can be described as follows:

- Term 1 of the dynamic formula is the difference between the gradient of the invert of the pipe and the friction gradient;
- Term 2 of the dynamic formula is the kinematic wave term;
- Term 3 of the dynamic formula is the diffusive wave term and takes into account backwater and wave attenuation;

- Term 4 of the dynamic formula is the local flow acceleration term;
- Term 5 of the dynamic formula is the lateral flow inflow term.

9.3 Flow simulation methods

9.3.1 Introduction

Three levels of sophistication for the hydrodynamics of flow in pipes are recognized:

- simple/empirical methods;
- other simplified methods;
- dynamic wave methods.

9.3.2 Simple/empirical methods

In these methods the flow is typically regarded as uniform and steady-state (see Table 2, Formulae (8f) and (9c)). The hydrological processes are also typically treated in a simple manner. The velocity at full flow conditions is typically used to compute a travel time (time of concentration) used to select an appropriate rainfall intensity value. They are used primarily for design of small development schemes (see 9.3.3).

9.3.3 Other simplified methods

In these methods non-uniform gradually varied flow are typically considered in some simplified form. Typically the lag time and in-pipe storage are taken into account. Possible simplifications in this category typically use a combination of one of the Formulae (8c) to (8e) with one of the Formulae (9b) or (9c) given in Table 2. They are effective for the initial design of large schemes, for the checking of existing systems, or for the simulation of network performance under long series of storm rainfall.

9.3.4 Dynamic wave methods

In these methods gradually-varied, non-uniform flow can also be simulated even under conditions of surcharge and backwater. Such methods use all the terms of the formulae (i.e. Formula (8a) or (8b) and (9a) or (9b) as appropriate) in Table 2. They can be used to check the performance of systems under conditions of flooding.

9.3.5 Selection of calculation method

For each level, the aboveground hydrological processes can be treated in either a simple or detailed manner (S or D in Table 3).

Table 3 gives guidance on the applicability of the methods. Methods may be combined for sub-catchments.

Table 3 —Applicability of flow simulation methods

Application	Method		
	Simple empirical methods	Kinematic wave methods	Dynamic wave methods
Design of small development schemes	S	S	b
Design of large schemes	a	S	S or D
Hydraulically simple road drainage systems	S	–	–
Checking performance against sewer flooding	a	a	S or D
Checking existing systems	a	S or D	S or D
Planning of outfalls//overflows	a	S or D	S or D
Impact on receiving water quality	a	S	S or D
Impact on receiving water quantity	a	S	S or D
Real-time control of a system	a	S or D	S or D
NOTE S Hydrological processes treated in simple manner. D Hydrological processes treated in detailed manner.			
a Not applicable.			
b Generally not recommended.			

9.4 Surface flood routing

Some models can also simulate surface sewer flooding by one of two approaches:

- a simple 1-dimensional approach in which the flow is routed along a single predefined flow path;
- more complex 2-dimensional approaches in which the flow is routed across a surface which simulates the ground surface profile including any barriers (e.g. walls, embankments).

For calculations of hydraulic roughness of surfaces the Manning Formula (2) is commonly used.

9.5 Validation of models

Calibration and/or validation of the models should be carried out whenever sufficient information is available. The procedures used depend on the sewer flow simulation model used. If suitable agreement between the model and the measurements is not obtained, the model input data should be checked and then the sewer records. Having identified possible causes of error, it is often necessary to confirm these by site inspection and then adjust the model accordingly. Data shall not be modified without justification based on an inspection of the system.

10 Hydraulic design

10.1 Capacity of drains and sewers

10.1.1 General

The capacity of drains and sewers shall be selected to meet the design criteria for the hydraulic and environmental performance of the system.

Pipes shall be selected to:

- transport the required design flows;
- limit sediment build up (see 10.2.1);
- ensure that the risk of blockage is reduced (see 10.2.2); and
- ensure that effective maintenance can be reasonably achieved (see EN 752).

In cases where deposits in the invert cannot be avoided, the reduced cross-section of the pipe shall be taken into account when calculating headlosses.

The hydraulic capacity of the pipes shall be calculated in accordance with Clause 7.

10.1.2 Foul drains and sewers

Foul drain and sewer systems shall be designed to collect and transport wastewater influents from domestic, trade premises to the point of treatment without prejudice to health and safety. Such design should also include allowances for future growth and for extraneous discharges up to such flow that justifies rehabilitation.

Having completed the design of the drain system, the interaction between the drain and the sewer system shall be checked.

Where a scheme is to be developed in phases, consideration should be given to the likely flows at each stage of construction so that either self-cleansing conditions are attained at least at times of daily peak flow or other cleansing arrangements are made.

10.1.3 Surface water drains and sewers

10.1.3.1 General

The hydraulic design of drains and sewers serving impermeable surfaces, such as roads and car parks, is dependent on the hydraulic performance of the interface between the impermeable surface and the drain or sewer system. The flow at this interface shall be adequately considered in order to minimize the impact of sewer flooding.

It can be necessary to provide a means of flow detention to intercept and hold back temporary peak storm discharges in order to avoid sewer flooding. The effects of the use of temporary storage of flow to reduce peak discharges within the drain and sewer system on the performance of the wastewater treatment plant shall be taken into consideration. Arrangements for maintenance and safety of these structures are required.

10.1.3.2 Use of simple/empirical calculation methods

For smaller schemes, a relatively simple, but safe approach is recommended, though use of simulation models is not excluded. Sewers are usually designed to run full, without surcharge, for relatively frequent design rainfall events in the knowledge that this generally provides protection against sewer flooding from more severe rainfall events. For these schemes, the full pipe design criteria determined in

accordance with EN 752:2017, 5.3.2.2, should be used. The designer shall use rainfall intensity and duration figures applicable to that particular area.

10.1.3.3 Use of more complex calculation methods

For larger schemes and for smaller schemes to be designed using a simulation model and for larger schemes, particularly where damage or public health risks are significant, it is recommended that the level of sewer flooding protection be directly assessed. The sewer system may be initially designed, as above, to give no surcharge with an appropriate full pipe design criteria. A sewer flow simulation model should then be used to check the level of flood protection against the sewer flooding design criteria in accordance with EN 752:2017, 5.3.2.3, and the design adjusted where the required sewer flooding protection is not achieved. There are cases, however, where adjustments are appropriate to avoid unnecessary over-design.

10.1.3.4 Exceedance flow routing

The designer shall assess risk of sewer flooding in events that exceed the design sewer flooding frequency, taking into account both the consequences of the sewer flooding and the frequency. Flow routes for excess flows should be investigated to determine the consequences and where possible, the design should be changed to minimize the impact. Where the risk of sewer flooding cannot be reduced by these means, the design frequency should be decreased.

10.1.4 Combined drains and sewers

For combined drains and sewers, the design flow rate is made up of runoff, which is by far the predominant component, plus an allowance for foul wastewater flows. The runoff component should therefore be estimated using the methods outlined in 10.1.3. The foul wastewater component should be estimated as described in 10.1.2. As the foul wastewater flows are usually considerably lower than the design flow rates, particular consideration should be given to self-cleansing velocities during dry weather conditions.

10.2 Design for self-cleansing

10.2.1 Sediment transport

For small diameter drains and sewers (less than DN 300) self-cleansing can generally be achieved by ensuring either that a velocity of at least 0,7 m/s occurs daily, or that a gradient of at least 1:DN (the inverse of the nominal diameter in mm) is specified. Steeper gradients or higher velocities can be required by national or local regulations or the relevant authority. To achieve self-cleansing conditions in sewers with low gradients there should be strict requirements for the bedding and accurate laying of the pipes.

For larger diameter drains and sewers, higher velocities can be necessary particularly if relatively coarse sediment is expected to be present.

Local guidance, in the form of tables or formulae can be available in national reference documents and may be used.

Where self-cleansing conditions cannot be achieved, provision should be made for adequate maintenance activities.

10.2.2 Minimization of blockages

To minimize the risk of blockage, drains and sewers should be smooth and laid to self-cleansing conditions. However, where the flows in the drain or sewer are low, steeper gradients (up to 1:DN/2,5) can be required.