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# Service activities relating to drinking water supply, wastewater and stormwater systems — Stormwater management — Guidelines for stormwater management in urban areas

*Activités de service relatives aux systèmes d'alimentation en eau potable, aux systèmes d'assainissement et aux systèmes de gestion des eaux pluviales — Gestion des eaux pluviales — Lignes directrices pour la gestion des eaux pluviales en zones urbaines*



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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 224, *Service activities relating to drinking water supply, wastewater and stormwater systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.



# Introduction

The objectives of stormwater management systems include effective control and management of flows; protection of water quality; preservation of water quantity; protection of the built, public and natural environments; water conservation and reuse; protection or enhancement of ecosystem health; protection or enhancement of public health, safety and welfare; protection or enhancement of social values; and facilitation of sustainable development and climate adaptation.

The Intergovernmental Panel on Climate Change[5] warns that many global risks of climate change are concentrated in urban areas. It indicates that risks are amplified for those lacking essential infrastructure and services or living in poor-quality housing and exposed areas. The key risks, all of which are identified with high confidence, include those of severe ill-health and disrupted livelihoods for urban populations due to flooding from a range of sources including pluvial, fluvial, storm surges and coastal flooding.

According to the UN Department of Economic and Social Affairs[6], the world urban population is expected to increase by 72 % by 2050, from 3,6 billion in 2011 to 6,3 billion in 2050, i.e. by the same amount as the world's total population was in 2002. Virtually all of the expected growth in the world population will be concentrated in the urban areas of the less developed regions, which are deemed to be vulnerable to flooding. The report states that flooding is the most frequent and greatest hazard for the 633 largest cities or urban agglomerations analysed. Mud slides are often associated with severe weather conditions and flooding, particularly in rural areas, and commonly will impact rural villages and small towns, or their associated transportation infrastructures.

Thus, climate change and urbanization with rapid growth in population in cities and surrounding areas are most likely to increase flooding and the risks associated with stormwater worldwide. Serious challenges for stormwater management are posed for an increasing number of stormwater utilities, which are responsible for the control of pluvial flooding, which is caused by rainwater entering and surcharging stormwater systems or remaining on surfaces and flowing overland or into local depressions and topographic lows to create temporary ponds.

The immediate impacts of urban flooding can include loss of human life, damage to property, disruption of traffic and other services and deteriorations of limited freshwater resources, water ecosystems and hygienic living conditions. Effective stormwater management systems can enhance the resilience of communities by reducing the likelihood and severity of pluvial, fluvial and coastal flooding.

Planning methods for stormwater systems have been established in most developed countries but they do not always apply directly to other countries with different conditions. In order to help deliver the best solution to the targeted area, the framework and planning processes should be standardised.

Urban stormwater management is usually the responsibility of municipal water and wastewater service providers. However, in some countries the urban stormwater system management is performed by separate entities specially established for this purpose. Sometimes these services are not financially supported from the municipal water and wastewater revenues but from stormwater levies applied to flood-vulnerable properties concerned and created for that purpose or a local governing authority.

While it is largely historically true that urban stormwater management has been the responsibility of municipal wastewater authorities, it is increasingly recognized that stormwater management may be best or additionally served through collaboration with other relevant stakeholders, such as forestry commissions (for forested hill and mountain sides), agricultural commissions (for upstream farming properties), river authorities or port commissions (for the management of tidal surges on both marine and freshwater bodies) or local governing authorities.

This document can be used for the evaluation of design, operation and performance of stormwater systems. When various kinds of measures are proposed, selecting the best option requires evaluation. The comparison between prospective and retrospective evaluations can lead to the continuous improvement of stormwater management. In providing a common process for the evaluation of proposals to plan/design/procure stormwater systems, this document facilitates fair trade among suppliers.



# Service activities relating to drinking water supply, wastewater and stormwater systems — Stormwater management — Guidelines for stormwater management in urban areas



## 1 Scope

This document provides guidance to stormwater management authorities and relevant stakeholders on both structural and non-structural stormwater management approaches. The guidance includes consideration of relevant policies, planning, design criteria and implementation processes for stormwater management, and performance evaluation. This document can be applied to new stormwater systems and to the extension or improvement of existing systems for both fully separated and combined storm and sanitary sewers.

This document is applicable to stormwater sewer systems as well as combined sewer systems.

This document is not applicable to sanitary sewer systems.

## 2 Normative reference

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 24513, *Service activities relating drinking water supply, wastewater and stormwater systems — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24513 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

## 4 General overview

### 4.1 Principles

The role of the stormwater system should be determined within the context of the whole river basin catchment and the other elements of the urban drainage system (see Figure 1). To determine this role account should be taken of integrated water policies reflected in any national or local regulations or by the relevant authority together with any requirements of the integrated river basin management plan. Account should also be taken of any policies resulting from integrated urban drainage management.

The principles for effective stormwater management include:

— **hydrology**: minimize the impact of urbanization and land management practices on the hydrology of a catchment, including base and peak flows;

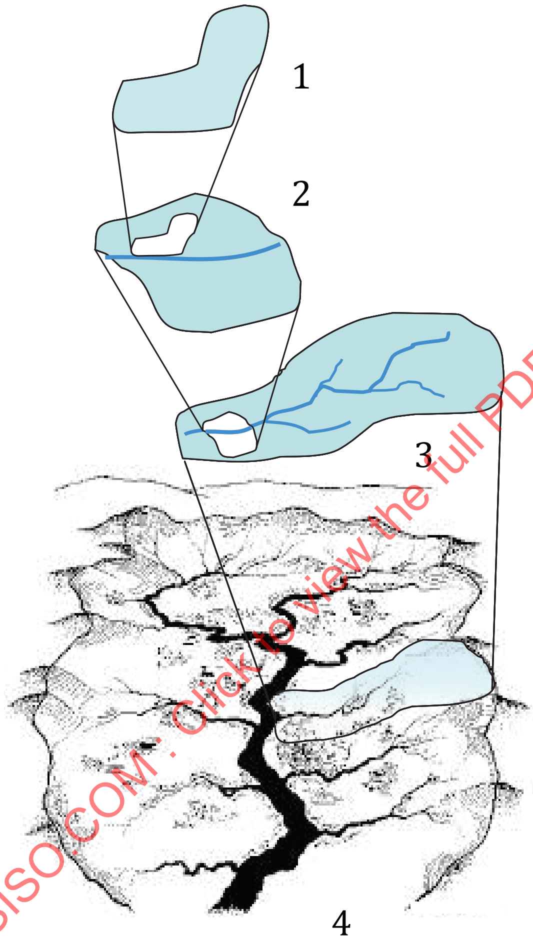
 

— **water quality**: minimize pollution entering into and discharged from the stormwater system;

— **vegetation**: maximize the value of riparian, floodplain and bank vegetation for flood attenuation, erosion control and water quality improvements;

— **aquatic habitat**: minimize the negative impacts of stormwater discharges on the integrity of aquatic habitats within the stormwater system; and

— **stormwater use**: promote opportunities to identify and use collected stormwater as an alternative water source.




**Key**

1 local drainage area

2 urban sub-catchment

3 city area

4 river basin

**Figure 1 — Relationships between local drainage areas, urban catchments and river basin**



## 4.2 Basic concepts

There are a number of basic concepts that support the objectives for urban stormwater management and that should be addressed during the process:

— flood-resilience and holistic risk analysis for new and existing systems;

— sustainability and responsible resource management;

— community consultation and involvement;

— consideration of interrelationships between catchments;

— consideration of changing climate, extreme weather and operational stress;

— consideration of lifecycle costs when selecting stormwater management alternatives;

— consideration of asset condition and rate of deterioration.

Figure 2 gives an illustration of a basic concept of a stormwater management system.

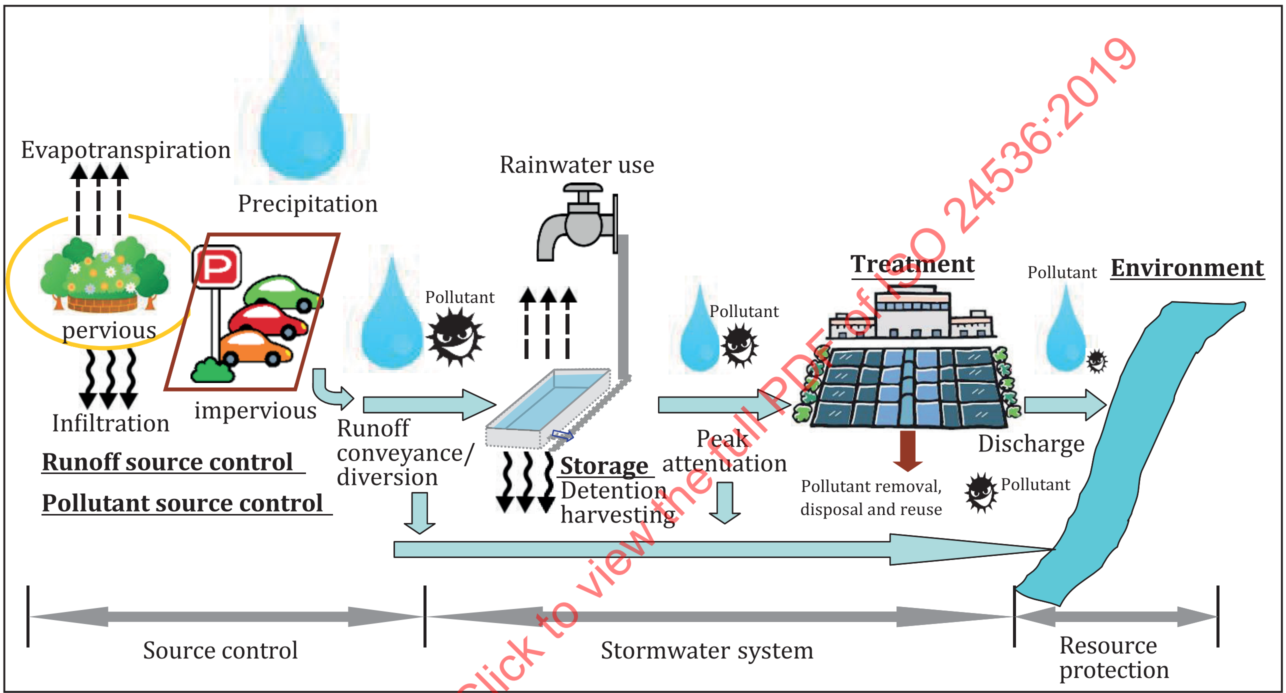



**Figure 2 — Illustration of the basic concept of a stormwater management system**

## 4.3 Stormwater management process

As illustrated in Figure 3, the stormwater process relies on the definition of functional and performance requirements adapted to the local objectives of the stormwater system. To ensure the fulfilment of these requirements a continuous management process can be followed that consists of investigation, assessment, planning and performance evaluation.

Both asset-related and non-asset-related solutions can be implemented to achieve the required level of performance.

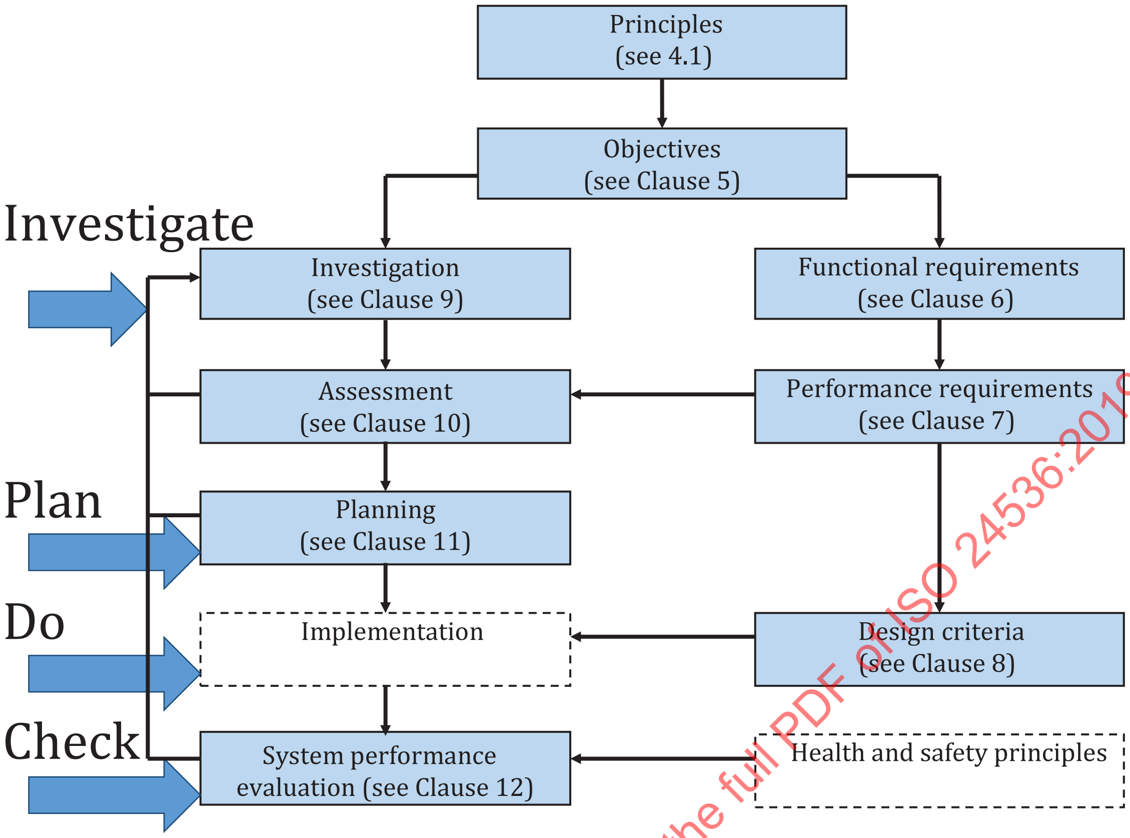



**Figure 3 — The stormwater management process**



## 5 Objectives

The objectives to be established by a wastewater or stormwater management utility should:

— be consistent with the stormwater management policy;

— be measurable (if practical).

Objectives can be short-, medium- or long-term and can vary according to the risk and opportunities within the catchment to public and environmental benefit. As such, urban stormwater management systems adopt a number of objectives to ensure that the risks are managed and opportunities realized.

The objectives of stormwater management are:

— effective control and management of flows;

— protection of water quality;

— preservation of water quantity;

— protection of the built, public and natural environments — infrastructure, property and resources;

— water conservation and reuse;

— protection or enhancement of ecosystem health;

— protection or enhancement of public health, safety and welfare;

— protection or enhancement of social values;

— facilitation of sustainable development and climate adaptation.

The objectives listed in Table 1 are the basis for determining the functional and performance requirements of an urban stormwater management system as illustrated in Figure 4.

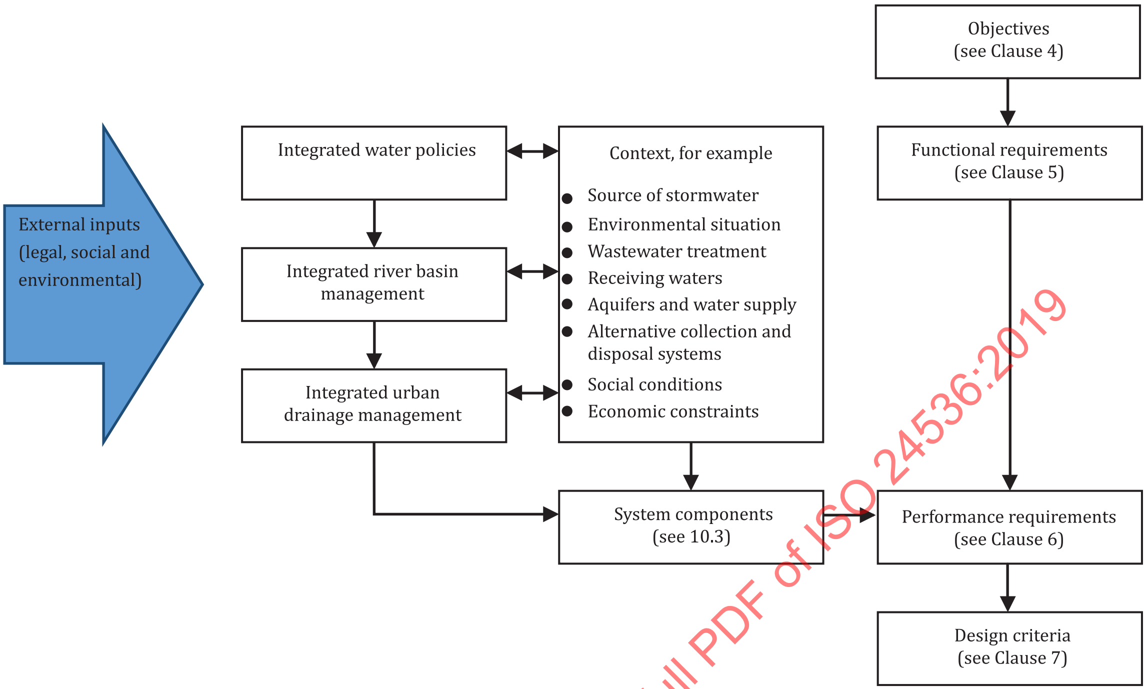



**Figure 4 — Process for determining performance requirements from objectives**

**Table 1 — Urban stormwater management objectives**

| Objective | Purpose |
|---|---|
| Effective control and management of flow volumes | — to optimize the stormwater system (e.g. pipe network, flow control device, storage, pumping facility)<br>— to improve the operation of the stormwater system<br>— to set up the stormwater system balancing risk and cost |
| Protection of water quality | — to support the management of water quality in the receiving surface waters and groundwater<br>— to maintain or improve the surface and groundwater quality in the receiving environment<br>— to reduce the potential for pollutants from the built environment entering the receiving environment<br>— to protect the stormwater at the nearest point of rainfall<br>— to design system resilience to cope with future change |
| Preservation of water quantity | — to support the management of water quantity in the receiving water<br>— to reduce negative quantitative impact of stormwater drainage from the stormwater system |

**Table 1** *(continued)*

| Objective | Purpose |
|---|---|
| Protection of the built, public and natural environments: infrastructure, property and resources | — to use surface water runoff as a resource<br>— to support the management of flood risk in the receiving catchment<br>— to minimize the risk of flooding during rainfall events, including upstream flood risk<br>— to protect the built environment from flooding and waterlogging<br>— to reduce damage to infrastructure and property, and associated financial impacts<br>— to protect resources from occupational health and safety hazards<br>— to reduce and control the potential for erosion and instability of stream banks, vegetation and combined sewer assets<br>— to protect morphology and ecology in receiving surface waters<br>— to preserve and protect natural hydrological systems on the site<br>— to drain the site effectively<br>— to manage on-site flood risk<br>— to design system flexibility/adaptability to cope with future change |
| Water conservation and reuse | — to maintain the total water cycle balance<br>— to minimize runoff and water wastage<br>— to maximize stormwater reuse through rainwater harvesting to supplement household, commercial/industrial, streetscape and parkland water supply needs<br>— to contribute to recharging of groundwater aquifers |
| Protection or enhancement of ecosystem health | — to preserve, retain or enhance natural drainage systems and protect ecosystem health<br>— to replicate natural flow regimes so that storm runoff hydrographs resemble pre-development patterns<br>— to support and protect natural local habitats and species<br>— to protect, conserve and retain aquatic habitats and biodiversity through preservation and restoration of natural habitats for flora and fauna<br>— to mitigate deterioration in environmental health<br>— to contribute to the delivery of local biodiversity objectives<br>— to contribute to habitat connectivity<br>— to create diverse, self-sustaining and resilient ecosystems |
| Protection or enhancement of public health, safety and welfare | — to minimize the risk of injury or loss of life and disruptions to human life, including flooding hazards<br>— to eliminate standing water and consequences of danger from mosquito- and other vector-related diseases |

**Table 1** *(continued)*

| Objective | Purpose |
|---|---|
| Protection or enhancement of public social values | — to ensure that social, aesthetic and cultural values are recognized and maintained when managing stormwater<br>— to contribute to attractive and liveable communities<br>— to promote land- and water-based recreational activities and stakeholder satisfaction<br>— to maintain the variety of uses available to the community<br>— to enhance wildlife habitat<br>— to protect and increase property values<br>— to maximize multi-functionality<br>— to enhance visual character<br>— to deliver safe surface water management systems<br>— to support development resilience/adaptability to future change<br>— to support community environmental learning |
| Facilitation of sustainable development and climate adaptation | — to ensure the delivery of best practice stormwater management through planning and development<br>— to integrate urban drainage into landscape design as part of the initial design phase<br>— to implement stormwater management systems that are economically viable in the long term<br>— to create functional, energy-efficient, low-carbon, climate-resilient cities<br>— to increase potential for land development<br>— to provide an alternative water source to reduce demand and increase reliability of long-term water supplies |

These objectives can and should be given full consideration for all types of development. The extent and way in which each purpose can be fulfilled will depend on site characteristics, development context and local objectives. The water quantity and water quality are likely to be the main drivers in determining the design philosophy for a site and these will be supported by expected levels of service for the stormwater management system. Maximising delivery of amenity and biodiversity objectives will often deliver on a range of other required planning outcomes/objectives for the site.

The objectives are not independent of each other. For example, using runoff as a resource will support both water quantity and amenity design objectives.

Generic criteria of good design are required to ensure a safe, functional and cost-effective sustainable drainage scheme. These generally fall into the categories listed in Table 2. In order to maximize opportunities and the associated benefits, these criteria should be considered at an early stage and fully integrated into the stormwater management and urban design process. In so doing, it is then possible to ensure that the scheme is truly multi-functional and delivering the highest return for the developer and for the community who will live there.

**Table 2 — Generic criteria of good design**

| Generic criteria | Explanation |
|---|---|
| Constructability | The design of a sustainable drainage system should ensure that it can be effectively and safely constructed. |
| Maintainability | The design of a sustainable drainage system should ensure that it can be easily and safely maintained. |
| Acceptability | The design of a sustainable drainage scheme should be acceptable to the public and other stakeholders. |
| Cost-effectiveness | The design of a sustainable drainage system should ensure that the site is drained to meet the required standards of service, while maximising the potential benefits from delivery of the criteria, at an affordable cost both initially to the developer and for those responsible for the long-term operation and maintenance of the system. |
| Health and safety | The design of a sustainable drainage system should ensure that it is safe for those living near or visiting the system, and for those involved in its operation and maintenance. |

# 6 Functional requirements

## 6.1 General

The function of an urban stormwater system at the broadest level is to collect, transport, store and treat stormwater in order to mitigate the water quantity and quality impacts of stormwater flows on the receiving environment. However, for each of these functional requirements, there can be legal requirements, public expectations and financial constraints, which include performance requirements.

Functional requirements are also linked to system goals and cover the drainage system (and sewer systems for combined sewer systems), pumping installations and other components, including requirements resulting from external constraints (e.g. effects on surface receiving water bodies and wastewater treatment plants). The requirements should be considered in respect of the whole system to ensure that additions or modifications to the system do not result in failure to meet the target standards. Asset deterioration monitoring, affordability and the need for society to understand the constraints of the system are critical factors.

Typical detailed functional requirements of an urban stormwater management system include:

— protection from surface water flooding;

— protection from sewer flooding;

— protection of surface receiving water bodies;

— protection of groundwater;

— maintainability;

— structural integrity and design working life;

— sustainable use of products and materials;

— sustainable use of energy;

— protection of adjacent structures and utility services;

— maintenance of the flow;

— watertightness;

— prevention of odours and emission of toxic, explosive and corrosive gases;

— prevention of noise and vibration;

— input quality;

— protection of downstream drainage systems;

— protection from natural disaster events;

— health and safety principles.

Functional requirements should be determined to ensure that the objectives of the urban stormwater management utility as listed in Clause 5 are achieved. Each functional requirement can relate to more than one objective.

## 6.2 Protection from surface water flooding

Surface water flooding has an impact on the health of people affected. It can also cause damage to buildings and urban infrastructure. The economic impact can be high and depends on the type of location flooded.

Pluvial flooding should be limited to nationally or locally prescribed frequencies, taking into account:

— the health and safety effects of the surface water flooding (whether it is from stormwater or a combined sewer system);

— the costs arising from surface water flooding;

— the extent to which any flooding on the surface can be controlled without causing damage;

— whether surcharge is likely to lead to surface water flooding of basements.

The hydraulic capacity of the drainage system should limit surface water flooding to nationally or locally prescribed levels and frequencies, taking into account backwater levels. The hydraulic capacity should allow for foreseeable increases in flow over the design working life of the system, including climate change projections.

Other forms of flooding can also impact on stormwater and combined sewer systems, including:

a) fluvial flooding – water from rivers and lakes which flows onto the land;

b) coastal flooding – water from the sea which flows onto the land;

c) sewer flooding – wastewater from drains and sewers which surcharges and flows onto land or backs up into a property;

d) groundwater flooding – water on land when the groundwater level rises and enters into underground structures, such as basements or garages.

The focus of this document is to deal with pluvial flooding. The interaction with other forms of flooding should be taken into consideration.

The effects of flows discharged into downstream receiving water bodies as well as erosion control and runoff reduction should be considered and managed appropriately.

Where there are components in the system which have a high risk of failure, measures should be taken to avoid or minimize the risk of surface water flooding in the event of failure of those components.

## 6.3 Protection from sewer flooding

Structures, including basements, connected to stormwater or combined sewer drainage systems should be protected from sewer backup caused by surcharge in the system.

### 6.4 Protection of surface receiving water bodies

Surface receiving water bodies should be protected from pollution.

The quality of discharges or other impacts from stormwater systems on the surface receiving water bodies should meet the local requirements (including environmental requirements).

### 6.5 Protection of groundwater

Groundwater should be protected from pollution. The effect of the stormwater system and any cumulative effect of multiple stormwater systems on the local recharge of aquifers and groundwater flood risk should be considered. Where infiltration drainage systems are proposed, the effects of runoff quality and quantity should be considered.



### 6.6 Maintainability

The system should be planned, designed, constructed and rehabilitated to allow effective maintenance activities that are safe (e.g. risk to personnel is controlled) and cost efficient. Adequate access and working space should be provided for maintenance purposes.

### 6.7 Integrity of structures

All the components of a stormwater system should be planned, designed, constructed, maintained, operated and rehabilitated to ensure structural integrity over the design working life.

### 6.8 Sustainable use of products and materials

Products, materials and their use/construction methods should be selected that minimize depletion of finite resources having regard to the design working life of the component and the potential for reuse or recycling, for example minimizing the volume of excavated material and its reuse.

### 6.9 Sustainable use of energy

The design and operation of the stormwater system should, so far as is practical, minimize the use of energy over the life of the system.

### 6.10 Protection of adjacent structures and utility services

The planning, design, construction, maintenance, operation and rehabilitation of any component of the stormwater system should not endanger existing adjacent structures or utility services.

### 6.11 Maintaining the flow

The system should be planned, designed, constructed, operated and maintained to reliably convey all permissible flows that can be collected by the system to the point of discharge, ensuring that the operation of the system is safe, environmentally acceptable and economically efficient.

### 6.12 Watertightness

All drains, pipes and ancillary structures should be watertight, unless designed to infiltrate to the ground (i.e. sustainable drainage systems).

### 6.13 Prevention of odours and emission of toxic, explosive and corrosive gases

Stormwater systems should be planned, designed, constructed, maintained, operated and rehabilitated as far as practicable to avoid odour nuisance, or emission of toxic, explosive or corrosive gases.

## 6.14 Prevention of noise and vibration

The system should be planned, designed, constructed, maintained, operated and rehabilitated so that noise and vibration are minimised.

## 6.15 Input quality

The stormwater system can be designed to receive stormwater runoff from both domestic and non-domestic sources. The quality of the non-domestic stormwater inputs should be controlled so that they do not compromise the integrity of the fabric of the system or its function or constitute a danger for the environment. National or local regulations or the relevant authority can give requirements for input quality.

## 6.16 Protection of downstream drainage systems

Flows and pollutant loads should be reduced or maintained to minimize impacts on receiving (downstream) drainage systems.

## 6.17 Protection from natural disaster events

The design and operation of the stormwater system should, so far as is practical, consider the potential impacts from a natural disaster event, for example storm surges, dam breaks or tsunamis.

## 6.18 Health and safety

### 6.18.1 General

Functional requirements should cover both public and occupational health and safety.

National or local regulations or the relevant authority might include more requirements regarding the health, safety and welfare of the public and/or personnel than indicated in this document.

### 6.18.2 Public health and safety

Stormwater systems should be planned, designed, constructed and operated so that the risk of public exposure to flooding and contaminated water in the case of a combined sewer system is minimized.

Appropriate communication measures should be taken to ensure public awareness.

Drinking water sources should be protected from contamination by stormwater runoff, infiltration and discharges.

### 6.18.3 Occupational health and safety

Stormwater systems should be designed, constructed and operated so that the occupational health and safety risks to personnel undertaking work associated with the stormwater system are minimised. In addition, welfare facilities should be provided where appropriate.

Those who are responsible for work in stormwater systems should ensure that the work does not present a risk to the health or safety of any person carrying out the work or any person who can be affected by their actions.

In addition, it is generally the responsibility of owners and operators to:

— provide safe systems of work, including arrangements for safe access to and egress from the stormwater system, and sufficient working space while in the system;

— ensure that their employees are properly instructed, trained and supervised in the work being carried out and in the safe systems of work in use.

# 7 Performance requirements

## 7.1 General

Performance requirements are targets to be met by the stormwater management system and components to achieve the overall objectives and stakeholder priorities for a catchment. They should represent protection of an existing valuable condition, or an improvement over existing conditions which are deficient.

The performance requirements should be defined according to the functional requirements described in Clause 6. They vary between countries and can be constrained by legal requirements, public expectation and financial factors.

Performance requirements involve establishing a goal, quantifying the necessary control, and determining the emissions from the system. Stormwater systems should be designed to achieve the desired outcomes, for example to prevent property flooding during a 10-year event, to prevent erosive velocities from damaging infrastructure or to maintain appropriate quality for reuse.

The determination of performance requirements should be supported by:

— **monitoring**: the effect of stormwater on its environment can be assessed through local measurements and used to define requirements that are specifically adapted to the local context;

— **modelling**: the use of mathematical and/or physical modelling can help to explore a wide range of scenarios and thus define more precisely the performance requirements. Monitoring data can be used to validate such models;

— **generic values**: when monitoring and modelling data are not available, data from literature may also be used, but previous methods are preferred whenever possible.

Performance requirements should be reviewed periodically and updated if necessary. The performance requirements for the system should be updated after major extension, augmentation, maintenance or rehabilitation.

In principle, the performance requirements for a rehabilitated system should be the same as those for a new stormwater system.

## 7.2 Examples of performance requirements

### 7.2.1 Protection of receiving water bodies

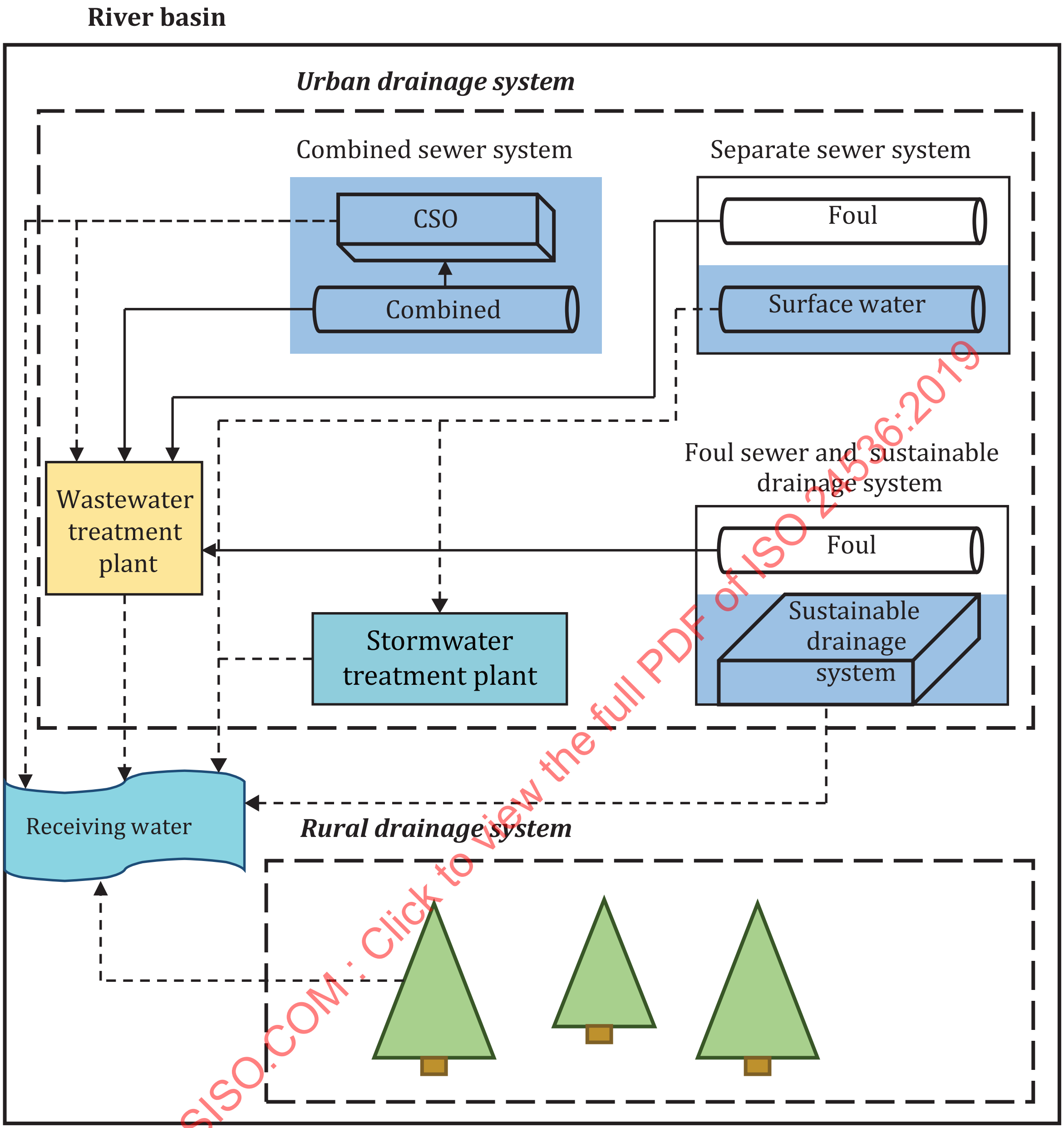
National or local regulations or the relevant authority can specify performance requirements in relation to the environmental performance of stormwater systems.

Environmental performance requirements for stormwater systems can be set in terms of emission limits for discharges or in terms of the impact on the status of the receiving water body (including inland surface water bodies, coastal water bodies and groundwater). The requirements should take into account the impact of other emissions, the anticipated frequency of discharges, and physical (e.g. scour due to flow velocity), chemical, biochemical and other relevant considerations.

Proposed controls on discharges from the stormwater systems should take account of the water environment in the river basin (see Figure 5).








**Key**

- - - -▶ flow of stormwater

——▶ flow of wastewater

parts within the scope of this document

Adapted from EN 752:2017, Figure 4.

**Figure 5 — Stormwater system in the river basin**

In particular, consideration should be given to:

a) the current status of the receiving water bodies within the river basin, including the chemical, biological and ecological status;

b) the objectives for the future status of the receiving water bodies;

c) any other proposed measures to improve or adversely affect the status of the receiving water bodies;

d) any policies for achieving the objectives.

Emission limits can be set in terms of the frequency and/or duration of the discharges as well as their physical, chemical or biological composition. Environmental modelling can be used to establish appropriate emission limits.

Examination of the statistics of precipitation suggests that capturing runoff from "smaller" storms allows management of a large fraction of the runoff events and runoff volume that occur from the urban landscape. The capture ratio of runoff volume is important to receiving waters because it is the frequency of small rainfall events that has the greatest negative effect on aquatic life in the receiving water bodies.

Alternatively, standards can be set by specifying a method of treatment (e.g. filtration/screening or vegetative treatment) to achieve environmental performance.

### 7.2.2 Protection from flooding

During rainfall events of small to moderate size, stormwater runoff is either captured by pervious surfaces and underlying permeable media (from where it may infiltrate or evapotranspire) or contained within the underground stormwater pipes and/or open-air transport channels (low-flow). During larger, less frequent storms, runoff will exceed transport capacity of the stormwater system leading to controlled or uncontrolled flooding (high-flow) (see Figure 6).

Effectiveness of drainage planning can be evaluated by how frequently the capacity of the "low-flow" system would be exceeded, and how severe the effect of flooding would be within the "high-flow" system. Frequency can typically be expressed as a recurrence interval. An example of a recurrence interval is the 10-year design rainfall event, defined as a rainfall with a 10 % probability of occurrence in any given year. Severity can be quantified through hydraulic modelling to determine specific characteristics such as length of roadway flooded, number of flooded structures and depth of flooding at structures.

Extreme flood protection criteria address the infrequent, extreme events where the capacity of the "high-flow" system is exceeded and the community and physical integrity of stormwater controls should be protected in a catchment area.

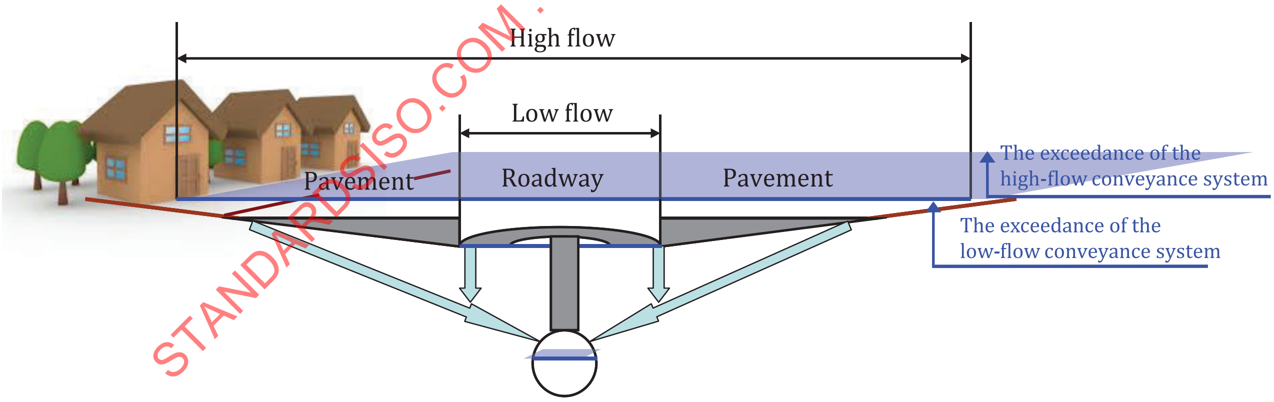



**Figure 6 — Low-flow and high-flow conveyance systems for stormwater control objectives**

Hydraulic performance requirements should be set taking into account the potential for damage and hazards.

National or local regulations or the relevant authority can specify performance requirements in relation to surface water or combined sewer flooding frequencies.

The sensitivity of the surface water flooding frequency to possible changes in rainfall due to climate change and changes in runoff due to increased levels of urbanization should be considered.



Performance requirements can also be set to limit the rate or volume of discharge from stormwater systems in order to limit flood risk in the surface receiving water bodies.

Hydraulic performance requirements for stormwater systems should take account of the wider river basin (see Figure 1) and in particular:

a) the current flood risk in the stormwater system and in the river basin;

b) the objectives for future flood risk in the stormwater system and in the river basin;

c) any other proposed measures to improve or adversely affect the flood risk in the stormwater system and in the river basin;

d) any policies for achieving the objectives for flood risk.

### 7.2.3 Structural integrity and design working life

The components of the stormwater system should manage any foreseeable imposed loads throughout the design working life without defects which would:

a) lead to unacceptable risk of loss of structural integrity;

b) impair the function of the system so that other performance requirements are not achieved.

# 8 Design criteria

## 8.1 Introduction

To ensure that the system achieves the performance requirements during its design working life, design criteria should be set which usually exceed the performance requirements. The design criteria should be set at a level which will ensure that the system continues to meet the performance criteria, taking into account any foreseeable changes over the life of the system. Design criteria should consider any changes expected over the design life of the stormwater system if these changes are not otherwise taken into account in the design.

Design criteria should include consideration of climate uncertainty, based on future climate projections. It is recommended that the results of ensemble models are used, forecasting seasonal temperature and precipitation variations into the future (e.g. 50-year projections). Stressor events, such as operational failures, should also be considered as part of the overall stormwater system resiliency.

The changes that should be taken into account can include:

a) increased or reduced flows due to new developments;

b) reduced flows due to changes in the development;

c) increased flows resulting from changes to existing developments;

d) reduced hydraulic capacity resulting from deterioration of the system or wear of pumps;

e) reduced hydraulic capacity due to build-up of sediments in the system drains;

f) climate change and changes to rainfall.

The issue of competing design approaches should be considered. For example, structural design criteria may compete with amenity design criteria (i.e. the best chosen structural material may not be aesthetically pleasing) and compromises may be necessary. In such cases, public consultation may be helpful in finding the best solution.

## 8.2 Hydraulic design criteria

### 8.2.1 Introduction

Hydraulic design criteria should take into account any changes in flows expected not only over a series of rainfall events but also over the design working life of the stormwater system. The potential effects of a) to f) in 8.1 should be considered. This is to ensure that the stormwater system continues to meet the performance criteria over its design life.

The frequency of an event may be expressed either as a return period or a probability of occurrence in any one-year period.

Design criteria can be set for:

a) the expected frequency at which no surcharge occurs in the drain and stormwater system;

b) the expected frequency at which a specified amount of surcharge occurs in the drain and stormwater system, for example full pipe design criteria (see 8.2.2);

c) the expected frequency of sewer or surface water flooding (this can occur without surcharge), for example flooding design criteria (see 8.2.3);

d) the impact of the flows from surface water outfalls on river morphology and ecology;

e) the impact of the flows from surface water outfalls on river flooding from surface receiving water bodies or on groundwater flooding;

f) the impact of the flows from aquifer recharge on groundwater flooding;

g) the impact of the flows on the operation of the wastewater treatment plant in the case of a combined sewer system;

h) the impact of contaminants in stormwater and especially combined sewer overflows (CSOs) on the receiving waters.

The nature of design criteria will depend on the type of design methods used.

In setting hydraulic design performance criteria for the stormwater system, allowance should be made for the design methods that are likely to be used. In all cases the scale of the consequences of surface water and combined sewer system flooding should be taken into account.

Where simple design methods (e.g. rational formula) are used, design criteria are typically expressed in terms of the frequencies of design rainfall events that will just fill the pipe without surcharge in the knowledge that this generally provides protection against sewer and surface water flooding from more severe rainfall events. The degree of flood protection will depend on local factors (e.g. topography, pipe gradient).

Where more complex methods (e.g. computer simulation) are used and it is possible to predict expected stormwater and combined sewer system flood frequencies, surface water and combined sewer system flooding design criteria should also be used.

Both the expected rainfall event frequency and the expected flood frequency may be expressed as a return period, which is the average period in years between two events, or a probability that an event will be exceeded in any one year. Where appropriate, time series can be used.

### 8.2.2 Full pipe design rainfall criteria

The design rainfall frequency is the rainfall intensity that causes the pipe to be just full. Different design criteria may be set for separate or combined sewer systems.

National or local regulations or the relevant authority can specify design rainfall.

In setting design rainfall criteria for use when stormwater or combined sewer system drains are designed for full pipe flow, the following points should be considered:

a) whether there are any connected basements not protected by anti-flooding devices, effluent lifting stations or pumping stations;

b) whether the surcharge is likely to lead to sewer flooding of basements;

c) whether design criteria for flood frequency are also specified for the design.

Examples of design rainfall frequency criteria are given in Table 3; however, the criteria can vary widely between countries.

**Table 3 — Examples of design rainfall frequencies for full pipe flow**

| Location | Design rainfall frequency[a] | |
|---|---|---|
| | Return period<br>years | Probability of exceeding in any 1 year<br>% |
| Rural areas | 1 | 100 |
| Residential areas | 2 | 50 |
| City centres/industrial/commercial areas | 5 | 20 |
| Underground railway/underpasses | 10 | 10 |

[a] For the selected design rainfall event the pipe should be no more than just full and shall be without surcharge.

SOURCE: EN 752:2017.

### 8.2.3 Flooding design criteria

Design surface water and combined sewer system flooding frequencies should be set in order to manage the risk of flooding, having regard to both the frequency and consequences of flooding.

NOTE The arrangement of the stormwater system with the above ground space are considered together to achieve these design criteria.

The effect of flooding will depend on the type of surface or building it affects. This will depend on the characteristics of the surface and the movement of the floodwater across the surface. The impacts can include damage to property and impacts on the health or safety of people. Design criteria should take account of the following:

a) Deep or fast flowing floodwater presents an increased hazard to people.

b) Flooding inside buildings can cause high economic damage and present a hazard to life and health.

c) Depending on its extent, flooding that is confined to external surfaces such as roads will often cause more limited damage.

For locations with a high potential for damage or hazard, detailed investigations should be undertaken, taking into account the movement of water and the effect of surface features (e.g. kerbs).

Different design criteria may be set for stormwater or combined sewer systems. National or local regulations or the relevant authority can specify design flooding frequencies.

Examples of design flooding frequency criteria are given in Table 4; however, the criteria can vary widely between countries.

**Table 4 — Examples of design flooding criteria for standing floodwater[a]**

| Impact | Example locations | Example of design sewer flooding frequency | |
|---|---|---|---|
| | | **Return period[b]** years | **Probability of exceeding in any 1 year** % |
| Very low | Roads or open spaces away from buildings | 1 | 100 |
| Low | Agricultural land (depending on land use, e.g. pasture, arable) | 2 | 50 |
| Low to medium | Open spaces used for public amenity | 3 | 30 |
| Medium | Roads or open spaces adjacent to buildings | 5 | 20 |
| Medium to high | Flooding in occupied buildings, excluding basements | 10 | 10 |
| High | Deep flooding in occupied basements or road underpasses | 30 | 3 |
| Very high | Critical infrastructure | 50 | 2 |

[a] When undertaking rehabilitation of existing systems and where achieving the same design criteria for a new system would entail excessive cost, a lower value may be considered.

[b] Return period should be increased (probabilities reduced) where the floodwater is fast moving.

SOURCE: EN 752:2017, Table 3.



Flood risk is different from the flood return period. From the standpoint of risk analysis, the probability that a 100-year flood will happen more than once in a given 100-year period is a representation of the risk. The following formula relates the return period to flood risk:

$$R = 1 - (1 - P)^N$$

where $R$ is the risk that an event with a probability $P$ be reached or exceeded at least once in $N$ years. For example, the risk that a 100-year flood will happen at least once during a 25-year period is not 1 % but 22 % (or 40 % for a 50-year period), as shown in Table 5.

**Table 5 — Flood risk associated with different return periods and mean probability of occurrence per year**

| Return period years | Mean probability of occurrence per year % | Flood risk for a given period of $N$ years % | | | | |
|---|---|---|---|---|---|---|
| | | $N = 100$ | $N = 50$ | $N = 25$ | $N = 10$ | $N = 1$ |
| 100 | 1 | 64 | 40 | 22 | 10 | 1 |
| 50 | 2 | 87 | 64 | 40 | 18 | 2 |
| 25 | 4 | 98 | 87 | 64 | 34 | 4 |
| 10 | 10 | 100 | 99 | 93 | 65 | 10 |
| 5 | 20 | 100 | 100 | 100 | 89 | 20 |

Adapted from *Stormwater Management Guide*, Ministry of Environment, Quebec, 2011.

### 8.2.4 Effect on downstream water bodies

Design criteria can be set for the impact of flows discharged from outfalls on the flood risk in receiving water bodies. The criteria may be given in absolute terms or by reference to the current conditions.

Such criteria can include:

a) controls on the flow rates and volumes for discharges from the area drained; for example:

   1) limiting the peak flow rate and volume of the discharge in prescribed rainfall conditions to specified values;

   2) ensuring there is no increase in the peak flow rate or volume in prescribed rainfall conditions.

b) criteria for the flood frequencies from the receiving water body; for example:

   1) no increase in flood frequency from the water body;

   2) limiting the flood frequency from the receiving water body to prescribed values.



## 8.3 Environmental design criteria

There are several approaches for setting design criteria for the control of pollution from stormwater systems, including:

a) the setting of uniform emission limits by national or local regulations or the relevant authority for general use with each of the different types of discharge;

b) the setting of site-specific emission limits by any national or local regulations or the relevant authority for individual points of discharge, to satisfy requirements for the quality and characteristics of the receiving water body, taking into account any environmental quality standards for the receiving water body and the specific needs of the receiving water body;

c) specifying a method of treatment for the discharge as nominated by the relevant authority to ensure that an adequate emission standard is achieved.

In many cases a combination of the approaches should be considered.

Uniform emission limits are generally set in relation to what is technically feasible for the different types of discharge. They form a baseline standard prior to the determination of site-specific limits which will not put the self-purifying capacity of the receiving water body at risk. They are unlikely to be applicable where discharge is to sensitive waters such as recreational areas, sources for water supply or lakes. Generally in such cases, more stringent site-specific emission limits will be necessary to satisfy the receiving water quality requirements.

The site-specific emission limit approach is sensitive not just to the effects of an individual discharge, but also to the combined effects of the whole range of discharges to receiving water bodies. These discharges, including those from industry, treatment works and non-point sources, can demand an integrated approach to the identification of solutions.

The principal advantage of method-based criteria is that there is no ongoing cost of sampling. The principal disadvantage is reduced confidence in the conformity. For this reason, method-based criteria are generally only set for low-risk discharges.

The relevant authority for environmental regulation can classify receiving water bodies according to current or projected uses or interests, for example:

— abstraction for potable supply;

— fishery;

— bathing or other water contact activities;

— special ecosystem.

The emission limits or method-based criteria can then be set by any national or local regulations or the relevant authority using, where appropriate, water quality simulation models.

## 8.4 Structural design criteria

Structural design criteria should be set, taking account of the actions on the structures.

Design criteria can include:

a) prescribing a design working life for each component;

b) prescribing the loads that each component should be able to withstand;

c) prescribing any special safety factors to be used;

d) limit states used for design.

## 8.5 Operation and maintenance (O&M) design criteria

Operation and maintenance (O&M) design criteria should be set to ensure:

a) the reliable and efficient operation of the system (e.g. eliminating blockages or pump failures);

b) the safety and welfare of operator personnel when carrying out operation of the system;

c) the safety and welfare of the general public;

d) cost-effectiveness over the lifecycle of stormwater management assets.



## 8.6 Amenity and biodiversity design criteria

### 8.6.1 Amenity design criteria

The amenity design criteria should be applied to maximize the amenity value for the development, for the local and wider community, and to:

— maximize multi-functionality;

— enhance visual character;

— deliver safe stormwater management systems;

— support development resilience/adaptability to future change;

— support community environmental learning.

The extent to which each amenity design criterion can be addressed by the designer will depend on local requirements and site-specific characteristics. Amenity objectives for stormwater management systems should be specified at a catchment or local level and these should be referenced and considered early in the design process.

These design criteria should be considered alongside design criteria for water quantity, water quality and biodiversity.

### 8.6.2 Biodiversity design criteria

The biodiversity design criteria should be applied to maximize the biodiversity value for the development, for the local and wider environment, and to:

— support and protect natural local habitat and species;

— contribute to the delivery of local biodiversity objectives;

— contribute to habitat connectivity;

— allow for diverse, self-sustaining and resilient ecosystems.

The extent to which each biodiversity design criterion can be addressed by the designer will depend on local requirements and site-specific characteristics. Biodiversity objectives for stormwater management systems should be specified at a catchment or local level, for example infrastructure strategies, and these should be referenced and considered early in the design process.

Both amenity and biodiversity design criteria should be considered together and at an early stage and fully integrated into the design process in order to maximize the opportunities that can be achieved by the scheme at no or minimal additional cost.

# 9 Investigation

## 9.1 Introduction

The process for investigating system performance is outlined in Figure 7.

Damaged, defective or hydraulically overloaded drainage systems represent a potential hazard through surface water and combined sewer system flooding and collapses, and through pollution of surface receiving water bodies, groundwater and soil. The problems found in existing stormwater systems are frequently interrelated and upgrading works will often be designed to overcome a number of problems at the same time. The investigation and planning of rehabilitation work should be carried out on defined catchment areas in phases, if appropriate, so that all problems and their causes can be considered together. The procedures described in this document can be applied in any stormwater system, but detailed application should take account of the age, location and type of system, the materials used in its construction, together with functional, geographical, topographical and meteorological conditions.

## 9.2 Purpose of investigation

The investigation is carried out in order to make an assessment of the performance of the stormwater system and its components. This can include:

— strategic planning;

— operational planning.

The purpose of the investigation influences the way in which it will be carried out (e.g. drains, combined choice of method, degree of detail, desired accuracy) and the way in which the results will be assessed.

The components of the stormwater system included in the investigation should be those that are necessary to fulfil the purpose of the investigation.

Examples include:

— sewers;

— gravity and pressure/vacuum networks;

— manholes, inspection chambers and other access facilities;

— pumping stations;

— rising mains;

— storage and retention tanks;

— infiltration tanks;

— sustainable drainage systems;

— combined sewer overflow structures;

— monitoring facilities, control facilities;

— outfalls, gravel and sand traps;

— flushing facilities;

— ventilation;

— sedimentation tanks;

— treatment facilities (where applicable).

## 9.3 Review of performance information

An indication of the type of performance problems, if any, on existing systems is likely to be known through reports of incidents such as drain collapses, flooding or polluted watercourses, and from previous investigations. Records of past incidents and any other relevant information should be brought together and a detailed review should be carried out to establish the scope of the investigations.

Examples of past performance information:

— records of flooding incidents;

— pipe blockage incidents;

— drain collapse incidents;

— rising mains failures;

— disease, injury or fatal incidents to operators;

— injury or fatal incidents to members of the public;

— drain damage incidents;

— conformity with discharge consents into and out of the system;

— closed-circuit television (CCTV) survey and visual inspection data;

— wastewater-related odour complaint incidents;

— hydraulic performance analysis;

— performance of mechanical/electrical equipment;

— results of monitoring;

— performance and condition of flow control structures;

— drain surcharge incidents.

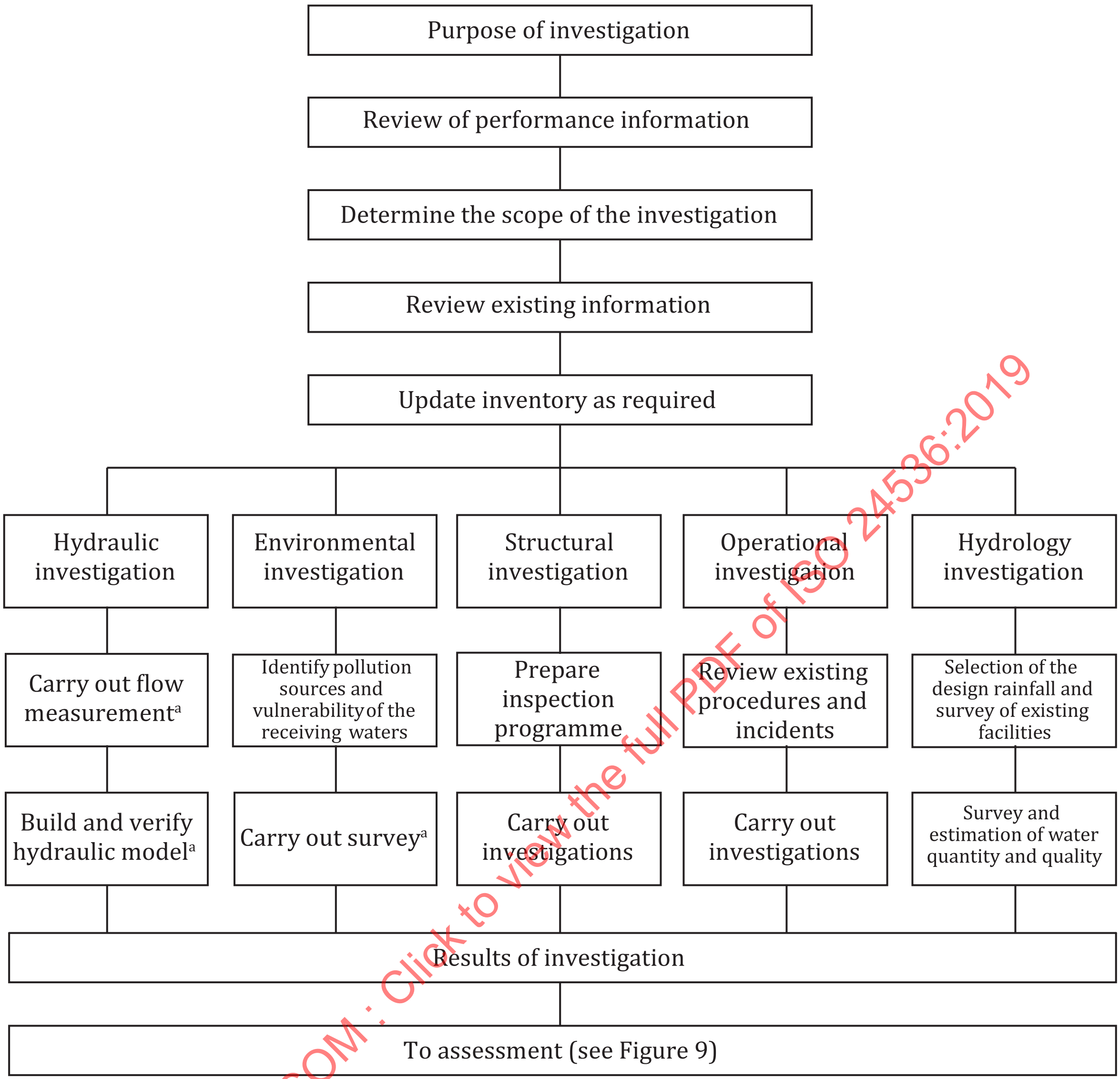
The relevant authorities will be the source of many of the records listed above. All appropriate records should be retained. Governance over performance reviews needs to be defined, establishing roles and accountabilities and reporting requirements for the overall stormwater system performance.

Where large numbers of complete or partial catchments are in need of investigation, the existing information collected may also be used to assign priorities to the investigation of the perceived problems in each catchment (for example by comparing the cost of the investigation with the benefit that might be achieved).

These can then be used to draw up a comprehensive, prioritised programme so that the catchments with the most serious problems are investigated first.






[a] Other types of investigations/monitoring are also possible.

**Figure 7 — Process of investigation**



## 9.4 Determine the scope of investigation

The process of investigation is illustrated in Figure 7. Following the review of the current performance information it will be possible to decide whether to carry out an investigation and whether the extent of the problems justifies an investigation of the entire catchment area. The extent and detail of the subsequent investigation of the hydraulic, environmental, structural and operational aspects should be determined.

## 9.5 Review existing information

The collection and review of all available relevant information about the stormwater system should be carried out and is the basis from which all other activities are subsequently planned.

This information should include historical records. In addition to the performance information listed in 9.3, examples include:

- inventory
  - age, location, dimensions, shape and type of material of all stormwater pipes and channels;
  - position depth and levels of manholes and the levels of connections to the manholes;
  - positions of connections to stormwater pipes and channels;
  - layout of ancillary structures such as CSOs, outfalls, pumping installations, sustainable drainage facilities, storage tanks and infiltration tanks, including details of any special plant (e.g. pump settings, control devices details and settings);
- relevant permits and legal requirements;
- previous operational, maintenance, structural and safety measures to overcome the problems;
- previous inspections;
- meteorological data (rain and evapotranspiration);
- previous hydraulic calculations or hydraulic models;
- previous flooding;
- topographical data;
- previous assessments of environmental impact;
- existing drain condition data;
- receiving water quality and use;
- groundwater levels and velocities;
- ground conditions, including infiltration capacity;
- groundwater protection zones;
- protected and sensitive natural habitat locations;
- previous test information;
- characterization of stormwater;
- information on proposed new development or redevelopment within the catchment area.

Some of this information can be available from as-constructed drawings and geographic information systems databases.

This information should be assessed to determine what further information is required in order to carry out the investigation.

## 9.6 Inventory update

Where the inventory is incomplete it should be updated so that a sufficient record of the stormwater system is available to carry out the investigation.

## 9.7 Hydraulic investigation

Testing and inspection procedures can be required in order to ensure an adequate evaluation of flows [wet and dry weather, infiltration, inflow through gaps in manhole tops (between the cover and frame), exfiltration and wrong connections]. Surveys can include precipitation and flow measurements, identification of wrong connections and groundwater measurements.

In some cases it is not possible to understand the hydraulics of the system without using a hydraulic model. This flow simulation model should be based on an as-built report updated after onsite investigation of the main works. However, a model is not usually recommended where:

— there are no known hydraulic problems;

— there are no CSOs;

— structural problems are to be solved using techniques which do not reduce the hydraulic capacity of the drain.

The selected hydraulic model should provide proven results. Calibration and/or verification of the models should be carried out whenever sufficient information is available.

The procedures used depend on the flow simulation program. If suitable agreement is not obtained, the model input data should be checked.

Having identified possible causes of error it will often be necessary to confirm these by site inspection and then adjust the model accordingly. Data should not be modified without justification based on an inspection of the system.

## 9.8 Hydrology

### 9.8.1 Selection of the design rainfall

#### 9.8.1.1 General

The most basic and important step for development of a plan is to define the design rainfall volume. Definition of the design rainfall volume requires a survey of the rainfall state of the region. The annual maximum rainfall for each duration is determined by using the data of the meteorological department. Then, on the basis of the concept of probability distribution, the rainfall is determined for required return periods of two years, 10 years, and so forth. Alternatively, the actual representative rainfall is applied as the design rainfall in some situations.

#### 9.8.1.2 Large, infrequent storm

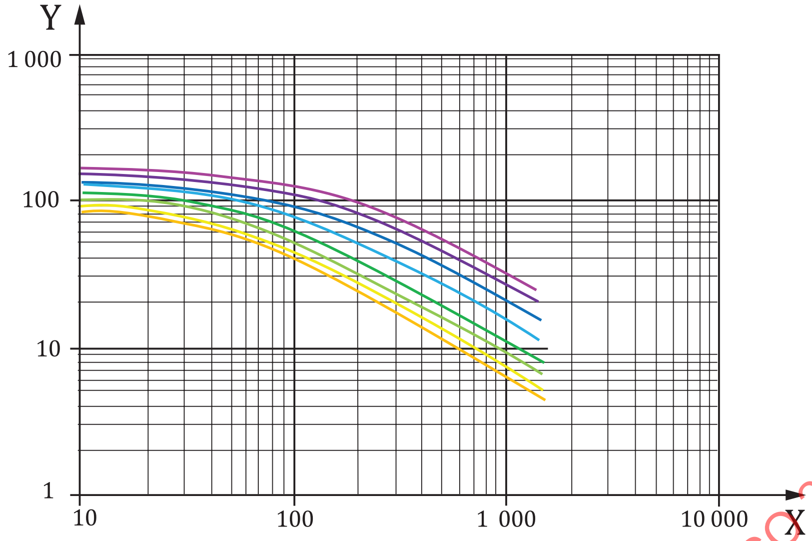
The intensity-duration-frequency (IDF) curve is a graphical representation of the probability that a given average rainfall intensity will occur. Rainfall intensity (mm/h) and rainfall duration (how many hours it rained at that intensity) are the parameters that make up the axis of the graph of the IDF curve and rainfall frequency (how often that rain storm repeats itself) is the parameter related to the IDF curve.

IDF curves are a commonly used approach because of their straightforward application. Peak flows can be derived through standard hydrologic methods by selecting the rainfall intensity from the IDF curve for a particular recurrence interval and time.

Alternatively, the IDF curve can be used to define the total rainfall volume for a particular recurrence interval and duration.

A design hyetograph can then be created using the design rainfall volume, a model distribution and full spectrum of recorded rainfalls. The highest reliability will be achieved through the use of a simulation using a representative rainfall events/record, which helps explain the response of the catchment or the sites that will be developed.

An example of IDF curves for Hanoi, Vietnam is illustrated in Figure 8.




**Key**

X duration (min)

Y rainfall intensity (mm/h)

Return period

200 years

100 years

50 years

20 years

10 years

5 years

3 years

2 years

**Figure 8 — An example of IDF curves for Hanoi, Vietnam**



### 9.8.1.3 Small, frequent storm

Determination of an appropriate design storm that leads to capturing the majority of the annual runoff volume relies on some type of statistical evaluation of precipitation records.

Cumulative probability distribution methods as shown below are used for defining the design precipitation volume, calculated by mean annual rainfall.

To construct a cumulative probability distribution, the historic precipitation record for a particular time increment (e.g. hourly) is sorted according to rainfall volume. Alternatively, the record can be subdivided into individual storms separated by a specified period of no rain. Events with a large rainfall volume are infrequent and have a low probability of being exceeded; conversely, small storms occur more frequently and their volume has a high probability of being exceeded. Such distributions are used to define the design precipitation volume as a percentile, that is, the fraction of events that are equal to or smaller than a particular precipitation volume.

The water quality criterion defines the size and drawdown rate of a stormwater control needed to capture and treat a certain fraction of the average annual precipitation or runoff volume. This capture volume is commonly called the water quality volume (WQV). The cumulative probability distribution method is recommended for estimating the rainfall depth producing the WQV because it is based on site-specific data covering the variability of rainfall patterns.

In addition, long-term continuous simulations are sometimes done to demonstrate the effectiveness of treatment or runoff prevention for a specific proportion of rainfall events.

### 9.8.2 Flood occurrence probability

Flood mitigation should be expressed by the flood occurrence probability corresponding to the design flow volume determined by taking into account the overbank flow volume, the extreme flood volume and the channel protection volume. Since flood occurrence varies depending on the topographical conditions and land-use pattern of a catchment and is not necessarily in the same chronological order, unified representation of the flood occurrence probability is difficult. On the other hand, the conventional rainfall probability is not equivalent to the flood occurrence probability due to differences in the design runoff volume calculation equation and topographical conditions, and is not readily understandable by ordinary people. In this context, there exists a concept of representing the development target by means of an hourly rainfall intensity. However, it is difficult to say that the rainfall intensity per hour is responsible for the flood that occurs because the time of concentration varies between points. In addition, the occurrence probability of such rainfall intensity cannot be expressed.

Accordingly, it is rational to express the flood occurrence probability by means of the rainfall return period (probable rainfall intensity) used for calculation of the design rainfall volume. When the flood state and cause are to be explained to the people in general, the probable rainfall intensity established as the target is necessary. The rainfall return period is also necessary for calculation of the assumed damage in the course of evaluation of investment effects.

Historical events should be considered in reference to the potential magnitude of flooding. The concept of the largest recorded rainfall is given in Annex A. Predicted impacts of climate change should also be considered.

### 9.8.3 Water quantity

Following the definition of the design rainfall volume, the design flow rate and the design flow volume are determined. This flow volume is the most critical element for planning of stormwater control facilities. The calculation approach differs depending on the stormwater control facilities to be planned. In the case of facilities with storage function and hydraulic structures such as orifices and pumps, the approach of preparing a hydrograph from a hyetograph, such as a time area method or a method using a simulation model, is employed for evaluation of the existing facilities. It is also necessary to understand at the same time the flow of rivers and channels within the basin related to the stormwater control facilities.

Rational formula is one method applicable for hydrological computations but is not suitable in situations with catchment storage, or for large or unusually shaped catchments. Other methods are available, such as the linear and nonlinear reservoirs model. For precise hydraulic simulations, models based on the Saint-Venant equations should be used.

### 9.8.4 Water quality

When there are overflows from combined or separate sewer systems, runoff from non-point pollution sources is likely to exert adverse effects on the water quality environment of receiving streams and coastal zones. Not only the flow volume but also the water quality requires a survey. In this event, the water environment of the basin concerned and the water quality of receiving water should be surveyed. Predictive calculation should also be performed concerning the water quality when the stormwater control facilities are completed and put into operation. Local conditions, i.e. the type of receiving waters, the type of stormwater system utilized and the quality as well as quantity of stormwater discharged, can sometimes dictate that the stormwater (and especially CSOs) may require treatment before its release into the natural environment.

### 9.9 Environmental investigation

The location of pollution sources (e.g. industrial, commercial and agricultural areas, roads) should be identified and their nature, quality, quantity and potential environmental hazards reviewed.

The environmental impact will depend on the nature of the stormwater influenced by land-use activities, whether it is mixed with wastewater and discharged from a combined sewer network or is collected and discharged into the groundwater or receiving waters, and their sensitivity to the discharge.

Investigations might be required to determine where leakage from the stormwater system is affecting groundwater quality, giving priority to drains which pass through aquifer protection zones or which carry particularly hazardous substances.

The quality of surface receiving waters should be ascertained to see whether they meet the requirements and, if not, whether the stormwater system is a significant factor.

Consideration should be given to other environmental factors such as noise, odour, visual intrusion and potential soil contamination.

When necessary, surveys should be carried out to provide any data not available from records.

### 9.10 Structural investigation

It is important to ensure that investigation of the system is selective in order to avoid duplication of previous work. The structural investigations may include either a complete survey of the stormwater system or more likely take a selective investigation. Consideration should be given to the age and location of existing infrastructure, geotechnical data, including the pipe bedding and surround, and the vulnerability of existing buildings and other utility services.

Wherever practicable, the recording of the structural condition of stormwater systems should be carried out by an indirect system (e.g. CCTV) in order to avoid personnel entering the system. Where it is not possible to obtain sufficient information from indirect inspection then direct inspection (e.g. by walking through the pipeline) may be used. The stormwater system should be cleaned as necessary to make it possible to record and assess the actual condition. The nature and quantity of any material removed can be relevant to the structural investigation. During the survey the system should be kept free from flows as far as necessary.

The condition of the system should be observed and recorded as accurately and comprehensively as practicable. A uniform coding system should be used to ensure that the results can be compared.

The observations recorded should include all those that could affect the structural integrity of the system.

Examples include:

— unacceptable fissures;

— deformation;

— displaced joints;

— defective connections;

— roots, infiltration, settled deposits, attached deposits, other obstacles;

— subsidence;

— defects in manholes and inspection chambers;

— mechanical damage or chemical attack;

— erosion (mainly on open channels).



Where appropriate, other qualitative and quantitative investigation techniques may be used. These include sonar (for pipes that are filled with water) and ground-probing radar or other geophysical techniques (e.g. for detecting voids behind the wall of the drain) or mechanical techniques (e.g. internal jacking to measure the stiffness of the side wall support). Smoke testing for detection of leaks and cross connections in sewers can also be carried out.

Investigation of the chemical composition of the groundwater and the soil should be carried out where this could affect the structural integrity.

The results of the structural investigations can also be relevant to the assessments of the hydraulic performance and environmental impact.

### 9.11 Operational investigation

Existing operational procedures, inspection schedules and maintenance plans should be identified and documented. Evidence that operational procedures, inspection schedules and maintenance plans are adhered to should be available.

The frequency and location of recorded operational incidents (e.g. blockages, pumping station failures, drain collapses, sewer flooding, flooding) should be reviewed.

The impact of operational problems on the hydraulic, environmental and structural performance of the system should be determined from incident records.

The causes of significant recurrent operational incidents should be investigated.

To deal with operational problems in the most cost-effective way, it is necessary to investigate and understand the causes. Economic impact should be considered in operational investigation (e.g. quantification of the value of flood damage avoided/incurred).

### 9.12 Existing facilities

When a plan is to be established, it is essential to survey the existing stormwater control facilities. In this event, a survey should be performed on the layout, capacities and condition of existing facilities. For the facilities capacity, it is necessary to identify not the values used during design, but the actual capacity value.

### 9.13 Social consequences

The design criteria should take into account the potential social consequences, including economic factors. Investigations should be conducted to determine the actual versus the designed impacts.

## 10 Assessment

### 10.1 Introduction

The performance of the system should be assessed against the performance requirements. The process for assessment is illustrated in Figure 9 and detailed in the following subclauses.

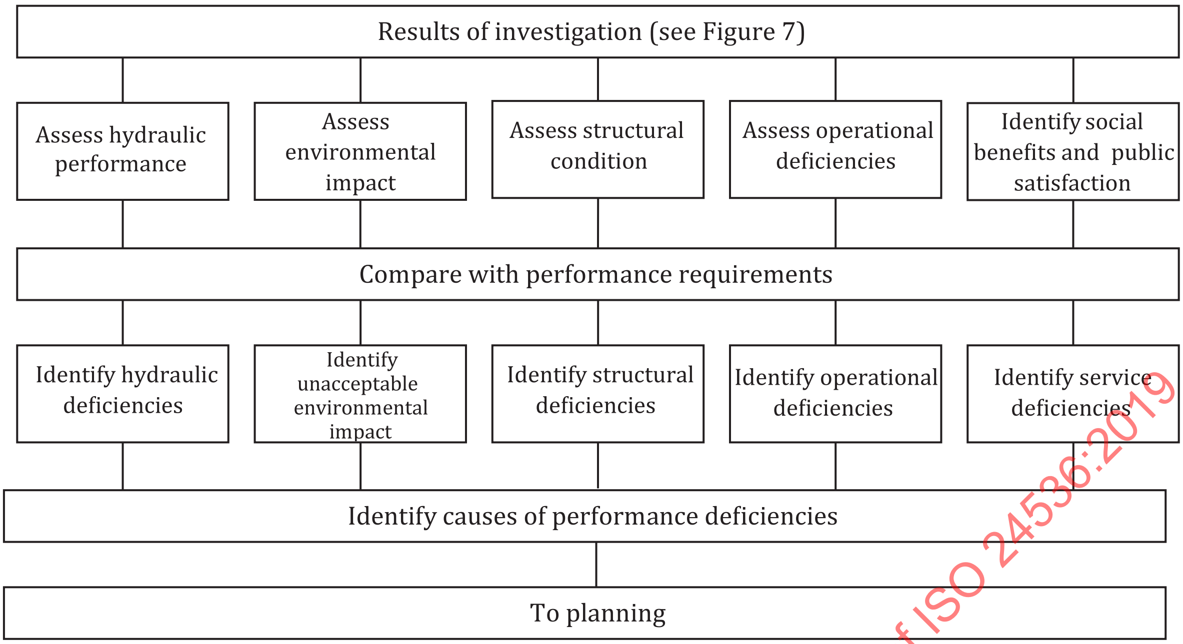



**Figure 9 — Process for assessment**



## 10.2 Assessment of the hydraulic performance

The results of the hydraulic surveys and/or the verified flow simulation model should be used to assess the hydraulic performance of the system for a range of rainfall conditions related to the performance requirements (see Clause 7).

## 10.3 Assessment of environmental impact

The results of the investigations should be considered together with information on the frequency, duration and volume of discharges to receiving waters, determined using a verified flow simulation model (see 9.7) where this is available or from site measurements. This information should then be used to assess the environmental impact (including impact on soil and groundwater) of the stormwater system.

The results of the investigation and the pollution sources location survey should be examined to identify:

— sources of pollution;

— exceedance of permissible concentrations and discharges;

— other deviations from permits.

The assessment of environmental impact should also cover the other impacts that the stormwater system can have on the urban environment:

— odours and toxic gases;

— noise and vibrations;

— pests;

— quality of runoff (sediment quality, nutrient loadings and other pollutants, e.g. hydrocarbons).

Both qualitative data (such as citizen complaints) and quantitative data (from monitoring campaigns) can be used to perform this assessment.

### 10.4 Assessment of structural condition

Once the system has been inspected, the next stage is to examine the results to identify those areas requiring action.

### 10.5 Assessment of operational performance

The operational performance of the system as measured by the number of operational incidents or failures should be assessed.

### 10.6 Assessment of social and economic benefits and public satisfaction

The level of stormwater services should also be assessed in regard to the related social and economic benefits and public satisfaction.

### 10.7 Comparison with performance requirements

The results of the assessment of the hydraulic, environmental, structural and operational performance should be brought together so that the overall performance of the system and its components can be compared to the performance requirements (see Clause 7).

Performance indicators are one method of comparing the overall performance of a system with performance requirements. Any performance indicators used should be:

— clearly defined, concise and unambiguous;

— verifiable;

— simple and easy to use.

### 10.8 Identification of unacceptable impacts

Details of those parts of the system where the hydraulic, environmental, structural or operational performance of the system or its components do not meet the performance requirements should be recorded.

### 10.9 Identification of causes of performance deficiencies

Based upon the results of the hydraulic, environmental, structural and operational investigations, the causes of performance deficiencies should be determined. The relative impact of each cause should be assessed in order to develop appropriate solutions and to set the priority for action.

### 10.10 Setting goals

The assessment should confirm that the objectives (see Clause 5), functional requirements (see Clause 6) and performance requirements (see Clause 7) of the stormwater system design are met. These should be supported by goals and targets to evaluate system performance. If certain targets are not being met, explanation should be provided in order to address deficiencies.

### 10.11 Prioritization of measures

The predictive effects of climate change, such as extreme rainfall events, can exceed the design capacity of the stormwater system. Progressive urbanization has also caused reduction in infiltration and water-retaining capacities, resulting in increased runoff.

In order to prioritize flood protection measures, it is recommended that flood-prone and high-risk areas are identified. Flood occurrence frequency, degree of damage, magnitude of risk, service level of the stormwater system and investment effects can be considered. This approach is considered to be effective for areas where flood damage occurs frequently and the amount of damage is larger.

Prioritization should also consider the environmental impact of stormwater runoff.

## 11 Planning

### 11.1 Planning principles

The planning of a stormwater system determines the configuration of, and requirements for, the main components of the system.

Planning principles should be determined, taking into consideration the following:

a) alignment with the objectives of stormwater management plans;

b) alignment with local/regional development plans;

c) the needs and expectations of stakeholders;

d) the benefits expected from the stormwater system;

e) the organizational and financial capability of the wastewater or separate stormwater utility/other responsible authorities;

f) budget and financial performance;

g) phased planning;

h) alignment with the existing municipal infrastructure;

i) location requirements and site restrictions;

j) the effects of the system on the built and natural environment;

k) the socio-economic effects of the system;

l) future climate-change projections.



### 11.2 Basic planning concepts

For development of the stormwater system, it is necessary to review beforehand what kind of facilities are needed. Principal aspects include:

a) layout: topographic conditions of the catchment concerned, approximate scale of planned components;

b) structure: soil conditions, approximate scale of planned components, materials, foundation methods;

c) hydraulic characteristics: water level of rivers and groundwater, hydraulic characteristics of planned components, response to change of flow;

d) water quality: of water bodies and groundwater, impact of planned facilities, influence on receiving waters;

e) amenity: existing context, characteristics of the urban environment, liveability of the community and the impact of the planned components;

f) biodiversity and ecology: existing biodiversity and ecology, connectivity and the impact of the planned components.

When stormwater causes flooding in an urban environment, detailed knowledge of the quantity and quality of this stormwater is important for the planning process. The sources of pollutants, generation of runoff, and temporal and spatial distribution of stormwater require an approach that targets quality and quantity of the various pollutants.

## 11.3 System components

### 11.3.1 Overview

The system components can include:

— source control facilities (green infrastructure such as green roofs or rainwater harvesting);

— conduits, sewers, swales and other overland flow features to convey stormwater;

— storage or retention (detention) basins;

— CSOs (as a structure);

— pumping stations;

— stormwater treatment facilities;

— infiltration facilities;

— stormwater harvesting and utilization facilities;

— residue disposal or reuse facilities;

— system controls, including real-time control.



### 11.3.2 Components for quantity control

#### 11.3.2.1 General

Components for quantity control can include any or all of the following parts.

#### 11.3.2.2 Pipes or conduits

Pipes or conduits are used for both collection and conveyance.

#### 11.3.2.3 Inlet structures

Inlet structures typically remove stormwater from surfaces such as streets or drainage ways. Stormwater flows into the inlet and is then transported through the system.

#### 11.3.2.4 Drainage ways

Drainage ways include open channels, streams, ditches and swales.

#### 11.3.2.5 Flow controls

Stormwater can require some type of flow control to help avoid overloading one or more components of the overall system. Flow controls include flow control orifices, weirs, check dams, gates, ditch checks and backflow preventers.

#### 11.3.2.6 Storage, retention or detention facilities

Urbanization alters the natural stormwater regime and newly developed areas must not adversely impact downstream areas. Storage, retention or detention facilities are used to minimize these impacts.

The storage, retention and detention facilities can be installed in, for example, gardens, parking spaces, parks, school playgrounds or sport fields. These facilities are installed either above or below ground. Stored or retained stormwater can be allowed to infiltrate into the ground or be directed into a drainage system and ultimately be returned to the natural environment.

#### 11.3.2.7 CSOs

CSOs are structures normally necessary in combined sewer systems to limit the flow during rainfall events to the capacity of the pipeline or the wastewater treatment plant.

#### 11.3.2.8 Sustainable drainage systems

Sustainable drainage systems simulate natural processes and flows. They are designed to collect, store, infiltrate, treat or reuse stormwater runoff before being released to the natural environment.

#### 11.3.2.9 Roadways

Roadways are primarily used to carry vehicular traffic. But in some cases, roadways are part of the stormwater system and can be used as stormwater conveyance routes. Vehicular traffic safety is of prime importance. Roadways used for conveying stormwater flows should be appropriately designed and carefully coordinated with roadway authorities, emergency and disaster authorities and utilities.

#### 11.3.2.10 Permeable pavements

Permeable pavements allow water to infiltrate and enter a gravel storage layer or proprietary modular geocellular system underneath the pavement surface. Infiltration can also occur through the bottom of the gravel storage layer.

### 11.3.3 Components for quality control

#### 11.3.3.1 General

Components for quality control can include any or all of the following parts.

#### 11.3.3.2 Storage facilities

Storage facilities include storage, retention and detention basins, infiltration facilities and constructed wetlands. They can also provide a range of other benefits such as amenity and biodiversity, habitats, recreational opportunities and mitigation of the urban heat.

#### 11.3.3.3 Debris and containment traps

A trap is a unit designed to remove trash, litter, debris, coarse sediment, vegetation and other particulate and particulate-associated pollutants from stormwater. Traps remove pollutants using screens, nets, baskets and rakes. Skimmers are used to remove coarse floatables, fats, oils and greases.

CSOs and their outfalls should be designed to minimize the impact of any discharges on the environment.

Factors to be considered include:

— flow rates;

— volume, duration and frequency of discharges;



— pollution concentrations and loads;

— hydro-biological stress;

— aesthetic impacts.

Treatment of discharges from CSOs can be required.

The pollution discharges to receiving waters from overflows and treatment works should be considered together.

#### 11.3.3.4 Hydro-dynamic separators

A swirling motion of fluid around a common centre in cylindrical chambers produces an inertial force that adds to the gravitational force found with normal sedimentation. These units, also called vortex, cyclonic or centrifugal separators, are sometimes fitted with chemical (e.g. polymer) addition equipment to enhance their suspended solids removal abilities.

#### 11.3.3.5 Vault setting tanks

Vaults are essentially underground multi-chambered storage elements that induce settling as the means of removing particulate pollutants and floatables. The constricted outlets cause a temporary rise in water level similar to retention basins.

#### 11.3.3.6 Cisterns

Cisterns and rain barrels are common stormwater controls. They can reduce the volume and peak runoff flowrate. They are also used for rainwater harvesting and utilization.

#### 11.3.3.7 Filters

Filters typically have two stages, a pretreatment stage (settling chamber) and a filtering stage (filter bed) with sand or other absorptive filtering media such as peat, compost, manufactured materials or combinations thereof.

#### 11.3.3.8 Bio-retention/biofilter

This unit typically consists of a grass strip, sand bed, ponding area, organic or mulch layer, planting soil, internal water storage zone, underdrains, green roofs, rain gardens and pocket wetlands. Bio-retention can be encouraged for on-site solutions for buildings, particularly commercial, public and institutional buildings, for example swale, filter strip and pocket wetland.

#### 11.3.3.9 Stormwater treatment plants

Stormwater treatment plants, which may have a number of integrated equipment and treatment processes, including the ones referenced above, at a single site.

### 11.4 Asset-related solutions

#### 11.4.1 General

A stormwater system may comprise both active and passive assets. Active assets can be manually or remotely controlled. Passive assets are fixed and cannot be adjusted. An active asset may include equipment to be used for discharge of stormwater into the environment so as to mitigate flood damage or reduce combined sewer overflow, and software to control the equipment. The active assets control the flow and the water quality. Control of the flow not only prevents flooding but also controls pollutants discharged via the stormwater system into the environment.

### 11.4.2 Stormwater network

A stormwater network can include any or all the following components:

- collection and conveyance pipes or channels;
- inlets;
- manholes;
- detention and retention facilities;
- pumping stations;
- treatment facilities;
- control structures (flow control orifices, weirs, check dams, gates);
- outfalls;
- sustainable drainage systems.

### 11.4.3 Sustainable drainage systems

Sustainable drainage systems are intended to collect, store, infiltrate or treat stormwater runoff before being released to the natural environment. Sustainable drainage systems can include:

- rainwater harvesting;
- green roofs;
- infiltration systems;
- proprietary treatment systems;
- filter strips;
- filter drains;
- swales;
- bioretention systems;
- trees;
- pervious pavements;
- attenuation storage tanks;
- detention basins;
- ponds and wetlands;
- rain gardens.

Besides volume control, sustainable drainage systems may also provide benefits for water quality by intercepting part of the pollution that is carried by runoff. The periodic removal of retained pollutants in soil or vegetation is required.

#### 11.4.4 Utilization of existing components

##### 11.4.4.1 General

The stormwater utility should review and implement necessary measures for optimal utilization of existing components. This includes evaluation of the stormwater system components and consideration of the addition of further facilities for optimal utilization of existing assets. The following measures should be taken into consideration.

##### 11.4.4.2 Optimization through augmentation, retrofitting and replacement

— Cross-section increase of pipes or conduits (e.g. pipe/conduit doubling)

In the hydraulic performance of the system certain pipe or conduit sections with insufficient cross-sections can cause backwater in the upstream areas of the system. Consequently, there is a possibility of flood damage both in these areas and in downstream areas through surface flooding.

In order to mitigate or eliminate the danger of flood damage in these areas, an increase of the relevant cross-sections should be considered before undertaking further protection measures in the endangered areas.

— Network of pipes/conduits and pumping stations

Distribution of stormwater among pipes and conduits can be provided by appropriate network configuration and control in order to fully utilize the network's capacity in the surrounding area for enhancement of the flow capacity and the prevention or mitigation of flood damage.

Depending on the size of rainfall area or shifting of rainfall, the place where flood damage is likely to occur can also vary. In this event, a thorough review based on existing rainfall data should be carried out to establish the optimal configuration and operation of the network.

— Improved use of existing facilities through renovation

In order to improve prevention and mitigation of flood damage, improved use of existing conduits as small storage pipes and improved use of existing pumping stations as stormwater storage facilities should be planned in the course of renovation.

The performance of existing stormwater storage facilities can be improved by introducing vortex flow regulators.

— Maximum use of existing stormwater storage facilities

Optimize the storage capacities of existing stormwater facilities by utilizing their capacity to the maximum extent as flow storage facilities.

— Development of the additional stormwater storage facilities to enhance the flow capacity in interaction with existing conduits

Flood damage can be prevented or mitigated through integrated system capacity enhancement, including development of stormwater storage facilities on the basis of evaluation of the capacity of existing conduits/sustainable drainage systems.

##### 11.4.4.3 Multi-purpose optimization of existing facilities

Combined sewer systems are designed to minimize overflows, especially during small rainfall events, and not to generate flooding during storm events. Lack of real-time control can lead to overflows while storage capacities in the system are available.

Real-time control enables dynamic operation of the stormwater system in order to optimize storage capacities – either retention tanks or in-line storage.

Real-time control relies on continuous monitoring and adjustments of actuated weirs, gates and pumps for which optimal set-points are computed and applied. In the case of predictive real-time control, the use of rainfall forecasts over the coming hours combined with hydrological and hydraulic modelling enable anticipation of future flows and water levels to increase the efficiency of the entire system.

#### 11.4.4.4 Obtaining benefit at an early stage by phased implementation

— Use of large trunk sewers under development as stormwater storage facilities

  Large trunk sewers require a long time for full development, but may be placed in service temporarily when development has proceeded to a certain extent to mitigate flooding.

  When full development of trunk sewers and pumping stations requires time, the upstream trunk sewers can be used as a temporary storage facility to mitigate flood damage.

— Early development of diversion facilities

  In order to ensure the flood control function of newly installed sewers, such as bypass trunk sewers, it is essential to allow water to enter at the point most effective for the prevention of flooding. Early development of suitable diversion facilities from the existing conduit system to the new trunk sewers should be considered. Note that the influence on the upstream side should be taken into account when designing the water diversion facilities structure from the existing conduit system to new sewers.

### 11.4.5 Asset-related solutions through collaboration with other projects

#### 11.4.5.1 General

In urban areas there are a large number of assets in addition to wastewater systems, including river control facilities, street drains and runoff volume retention facilities (e.g. ponds and forests in parks). By using the capacity of these other assets (infrequently) to the maximum extent through collaboration with their relevant authorities, it can be possible to prevent or mitigate flood damage.

#### 11.4.5.2 Collaboration through direct connection of the river retention

Collaboration through direct connection of the river retention basin with the stormwater storage facilities of the stormwater system.

#### 11.4.5.3 Collaboration with channels

Drainage systems other than rivers, such as channels, can be effective in mitigating flood damage. The capacity of existing channels and canals should be evaluated and measures to ensure effective interaction with the stormwater system should be developed. The existing channels' capacity to store and convey excess stormwater flow without sustaining erosion damage should be evaluated and, if necessary, the channels should be lined in order to prevent such damage.

#### 11.4.5.4 Collaboration through reinforcement of the capacity of intake facilities

In the event of local heavy rainfall within an extremely short time, there are cases in which the intake points at which stormwater flows into sewers act as a bottleneck, causing flood damage.

Through collaboration with road authorities, provision of transverse and longitudinal street gutters, the addition of stormwater inlets or the replacement of solid covers with grating covers, flood disasters can be prevented or mitigated. Gutters should be designed so that their intake capacity does not readily deteriorate as a result of blockages from fallen leaves or waste. Reconstructing the cross-section of roads as a trough can prevent damage to houses and other assets.



**11.4.5.5 Installation of small stormwater storage and infiltration facilities under street gutter gullies**

Roads have high runoff ratio, but their space is a wide valuable space within the city. It is worth considering mitigating flood damage by installing stormwater infiltration storage and infiltration facilities under street gutters or pervious pavements, thereby using the road space more effectively. Stormwater infiltration and storage facilities should be provided at points where road runoff concentrates, taking the necessary space for emergency vehicle traffic into consideration.

**11.4.5.6 Collaboration with parks, green spaces, school playgrounds, parking spaces, paddy fields and farm ponds**

Through collaboration with relevant stakeholders, parks, green spaces, school playgrounds, paddy fields and farm ponds can be used to mitigate damage up to a certain design flooding level

Specifically, there are cases of using abandoned farm ponds for stormwater storage, storing stormwater in paddy fields, school playgrounds or ball fields by lowering the ground level.

**11.4.5.7 Collaboration with land-use authorities**

Runoff volume into the stormwater system is greatly influenced by land use. Maintaining or expansion of the use of land with a relatively small runoff ratio should be considered to mitigate flood damage.

Specifically, efforts should be made to preserve forests and trees in collaboration with forestry and park authorities.

Runoff from agricultural practices can profoundly affect the quality and quantity of runoff from agricultural areas. Good practices include contour ploughing, the provision of protective unused land strips along river and stream banks, and livestock watering facilities to prevent livestock from entering rivers and streams for watering.

**11.4.5.8 Collaboration with urban planning divisions to provide guidance for development of stormwater retention and infiltration facilities**

In urban development activities, it is possible to include measures to reduce runoff and increase infiltration of stormwater, both in public areas and private properties. In this event, efforts are made to mitigate flood damage in collaboration with the urban planning division by providing guidance for development of facilities capable of runoff retention on the basis of the state of the stormwater system and the receiving waters.

Individual stormwater storage and infiltration facilities in public and private properties can suppress runoff volume to the stormwater system.

**11.4.5.9 Collaboration with building code authorities**

Encouragement of building code updates to incorporate climate resilience, including considerations for the construction and renovation of stormwater management systems, in particular for residential, industrial, commercial, public or institutional buildings.

**11.4.5.10 Collaboration with the river authorities**

A river retention basin can be in the same structure as a stormwater storage facility. Prevention and mitigation of flood damage at low cost are possible by constructing multi-function facilities with partitions.



#### 11.4.5.11 Collaboration with the river division and local landowners to enable permanent and effective use of temporary retention areas

In the course of development activities, regulations can require the construction of so-called temporary retention areas as stormwater infiltration and storage facilities to suppress runoff to rivers.

In collaboration with the respective landowners, efforts should be made to ensure the permanent and effective use of such retention areas by identifying their function as part of the stormwater system in planning instruments and improving their functionality (e.g. by modifying the outlet) to ensure maximum use of their capacity relative to the needs of the stormwater system.

When implementing the measures listed above, stormwater utilities and other stakeholders should pay attention to the related operation and maintenance activities. These should be carried out to allow for the proper functioning of the facilities and systems and include measures such as cleaning stormwater inlets and storage tanks of collected sediment and debris, removing obstructions (e.g. tree branches) from channels and streams after each storm and repairing any resulting erosion damage.

#### 11.4.5.12 Collaboration with emergency response departments

Consult with emergency response authorities regarding flood risks and mitigation measures, emergency response and access requirements. These should be considered as part of system design and maintenance.



## 11.5 Non-asset-related solutions

### 11.5.1 General

In the past, measures to control flooding have generally been asset-related, such as construction of stormwater sewer systems.

A trend for locally concentrated heavy rainfall events with flood damage has been identified across the world. Planning processes are being used to develop step-by-step solutions for stormwater management to address this trend. Because of the long time required for the development of new facilities, as well as widespread financial constraints, it is difficult in practice to cope with such a trend simply by installing asset-related measures.

With this background, it is necessary to minimize flood damage by incorporating non-asset-related solutions, in addition to conventional asset-related solutions, for example installing flood-proof doors and windows, raising electrical sockets or signing up to receive flood warnings.

Non-asset-related solutions based on self- and cooperative-supporting activities are expected to play extremely important roles as a part of future stormwater measures. Such self- and cooperative-supporting activities cannot be expected to develop unless it is understood what kind of actions are to be taken by local residents. It is essential to deepen local residents' understanding of these self-supporting and cooperative stormwater flood prevention measures and to obtain their participation by identifying the actions required.

In most cases, non-asset-related solutions can demonstrate effectiveness when combined with asset-related solutions. In developing an effective stormwater management approach it is necessary to incorporate the efforts of reaching the goal with a step-by-step approach based on the regional conditions.

### 11.5.2 Demand control

With increasing urbanization, there is an increased demand on stormwater systems. If this demand for stormwater systems can be controlled, the impact of flooding in urban areas and water environments could be mitigated while contributing to saving of the investment and operations and maintenance costs for the stormwater system.

A demand-control approach can include:

— charges and duties related to stormwater drainage on the basis of the size or ratio of the impervious area;

— subsidies for a part of the costs of installing the facilities to store stormwater on-site;

— deregulation of the floor area ratio and building coverage of a new building, provided that the stormwater storage facilities are integrated within the building;

— facilities which promote sustainable drainage systems or green infrastructure.

### 11.5.3 Flood resilience approaches

The objectives of flood resilience approaches include:

— flood avoidance: minimizing the risk of floodwater reaching property by redirecting water;

— flood resistance: minimizing the risk of floodwater entering buildings by closing/protecting entry points;

— flood resilience: floodwater might enter buildings but resilience features will ensure that no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated.

Approaches to fulfil these objectives include:

— building aperture technologies;

— perimeter technologies;

— building elevation above flood level.

### 11.5.4 Disaster preparedness and response

#### 11.5.4.1 Preparedness

The following actions should be considered to ensure an appropriate level of preparedness and provide an efficient response to stormwater crisis events:

— identify and dedicate resources (e.g. human, physical, financial);

— develop an emergency action plan (EAP);

— train operating team(s) to implement the EAP;

— disseminate the EAP and communicate this to the public;

— engage with the population located in the critical areas to make them aware of the nature of the risks, and what they should do in each emergency situation;

— regularly verify and update the EAP.

It is necessary to have clear predefined procedures, accessible in dedicated documents, covering all the actions to be engaged before, during and after the crisis event. These should be contained in the EAP document.

The main topics to be covered by the EAP are:

— identification of risks to be considered (e.g. flood prone areas);

— definition of roles and responsibilities of all the relevant stakeholders, such as:

  — stormwater utility;

  — emergency response authorities and organizations;

  — subcontractors;

— definition of warning levels and associated thresholds, considering early warnings, on-site monitoring and other possible observations. As an example, five levels can be considered for flooding:

  — **level 0 – no warning**: no rain expected;

  — **level 1 – flood watch**: rainfall event expected;

  — **level 2 – flood warning**: flooding expected;

  — **level 3 – flood alert**: major flooding expected or flooding event currently occurring;

  — **level 4 – post-event recovery**: flooding and rain ceased;

— definition of actions according to the previous warning levels, with all relevant information (e.g. contact details of all stakeholders).

Table 6 provides examples of actions related to flood management.

**Table 6 — Warning levels and actions related to flood management**

| Warning Level | Description | Actions |
|---|---|---|
| 0 | No warning (flood clear) | Routine activities including training or operational teams, regular communication with population and dissemination of EAP. |
| 1 | Flood watch | Enhanced supervision, restricted communication, verification of the functioning of communications with remote sites, verification of the functioning of monitoring sites, launch of rapid inspections of flood protection structures and clearing of debris if required. |
| 2 | Flood warning | Thorough supervision, extended communication, ensuring on-site teams in guard houses, contact with emergency response authorities. |
| 3 | Flood alert | Crisis supervision with all key people, triggering of alarms to warn population, activation of satellite phones, close interaction with emergency response authorities. |
| 4 | Post-event recovery | Informing the population, supporting emergency response authorities, sending operators as soon as possible to check structures and perform observations, debriefing. |

— information management: defines how the EAP should be disseminated;

— training procedures;

— revision procedures: defines how and when the EAP should be revised in order to ensure that it remains up-to-date (e.g. contact details of stakeholders).

### 11.5.4.2 Self-supporting measures

Self-supporting measures contribute to mitigation of flood damage in the downstream area as well as supporting self-defence reaction on the basis of understanding the effects of public-supporting measures and any residual flooding state. It is essential that the representatives of the local residents and the government select the measures that can be introduced. The prerequisite for self-supporting measures is the cooperation from local residents and can include measures such as:

— frequent cleaning of road stormwater inlets;

— placement and stacking of sand bags during heavy rainfall;

— local flood-monitoring protocols;

— self-training to prepare local residents for disasters;

— collaboration with disaster volunteers;

— installation of removable flood barriers.



#### 11.5.4.3 Cooperative-supporting measures

The cooperative-supporting measures involve activities to mitigate flood damage by means of:

— cooperation between residents, asset owners and facility administrators within the region;

— notifying neighbours and business owners in case of evacuation;

— collective evacuation activities;

— communication training on a routine basis, such as clearing street gutters and catch basin inlets in front of properties of fallen leaves and other debris.

#### 11.5.4.4 Public-supporting measures

Public-supporting measures can include the establishment of an efficient maintenance system, collection and supply of information, collaboration with other entities and assistance to self-supporting activities.

Public-supporting measures are often limited by available financial resources to reduce flood risks through effective measures, development of facilities and operation of existing facilities. Examples of such measures include:

— incentives such as reduced charges to customers that can demonstrate on-site retention, use or re-use of stormwater;

— financial support for installing backflow preventers or pumps to avoid basement flooding during severe storm events.

In cases where flood risks are difficult to reduce, it is important that the administrations provide support to the self-supporting measures by means of advance publication of the state of development of drainage facilities and the provision of real-time flood information.

Public-supporting measures should also include public education on flood risk and flood risk reduction initiatives. Education on maintenance of backwater valves, sump pumps and other lot-level flood risk reduction mechanisms is also prudent.

### 11.5.5 Emergency response and recovery

#### 11.5.5.1 General

Disasters usually strike suddenly and unexpectedly. The immediate response to an initial flood inundation incident should be undertaken as part of organisational emergency procedures. A joint tactical and operational coordinated response with emergency services and relevant authorities should be initiated to deal with the immediate effect of the incident(s).