DS.503
Highway Drainage

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1 Introduction

a. This guidance is for use by developers and engineers when planning, designing and constructing surface water drainage systems intended for adoption under an agreement made in accordance with Section 38 and section 278 of the Highways Act 1980 and/or Section 104 of the Water Industry Act 1991.

b. Section 104 of the Water Industry Act 1991 only applies to the adoption of assets predominantly used for drainage from buildings or paved areas belonging to buildings. Water companies do not have a statutory duty to adopt or maintain assets where the main purpose of which is to deal with drainage of streets, land drainage runoff, or flows from watercourses or groundwater.

c. Where the proposal includes significant technical challenges (e.g., a bespoke in-situ reinforced concrete structure or a novel design), specialist technical vetting may be necessary by the water company. Vetting will be required by the highway authority if it is to be located in a future adoptable highway. In these cases, the designer is advised to consult with the water company and the highway authority at the earliest opportunity.

d. The successful design requires the designer to liaise with a variety of stakeholders such as the Lead Local Flood Authority from the earliest stages in the design of the development.

e. The developer may decide how much of the system is offered for adoption under the section 38 agreement, provided that the adopted system is a continuous network to an effective discharge point.

f. The local authority as planning authority has a role in approving the design of any surface water system. In this role, they are required to consult with others, including the Lead Local Flood Authority and, in some circumstances, the Environment Agency and any internal drainage board. The local authority is also required to clarify the long-term maintenance arrangements for the system.

g. Surface water drainage proposals should fully explore the surface water drainage hierarchy (as per London Plan Policy SI 13) and provide evidence to support alignment with national and local flood risk strategies and policies before connection to a sewer is considered. If connection to a sewer is required for surface water, water, companies will expect that upon making a S104 Application to adopt a sewer system or a S106 Application to connect to a public sewer, a developer will be able to present robust evidence discounting the discharge of surface water to ground via infiltration or to a watercourse for all or part of the site and that this evidence has been reviewed and approved by the Lead Local Flood Authority and the Local Planning Authority.

h. In some cases, temporary high groundwater levels, or from a watercourse or other surface water body can restrict the discharge of surface water from the adopted system. The design should take into account the likely frequency and duration of these conditions.

i. A successful drainage strategy should include considerations of future maintenance. Highway Authorities can only adopt certain types of SUDS components and early consultation is required to ensure that they are maintained in perpetuity.

j. Failure to comply with the guidance in this design standard could lead to the drainage system and development not being adopted by the Highway authority. To avoid this, any departures from this design standard must be formally agreed.

2 Design Principles

2.1. General Design Principles

a. Drainage design should be undertaken holistically with other aspects of design (e.g., the site's topography, geology, street layout, the location of any public open space, soil remediation and ecological considerations) in an integrated manner. It should, therefore, be considered at the early stages of design.

b. During extreme weather, if the capacity of the drainage infrastructure becomes overloaded, water will flow across the surface of the site. In a holistic design, the layout of the whole development should take account of the potential risk of flooding to surrounding areas, not just the drainage layouts, and the effect of any overland flows from adjacent sites. The design should work with the contours of the land to manage exceedance flows safely.

c. Guidance on holistic design can be found in Building for Life 12, CIRIA Report C635: Designing for Exceedance in Urban Drainage - Good Practice, CIRIA Report C723: Water Sensitive Urban Design in the UK and in CIRIA Report C753: The SUDS Manual. This applies equally to any drainage system (foul or surface water) proposed for the site.

d. Developers are reminded of their duty to appoint a principal designer in accordance with the Construction (Design and Management) Regulations 2015. The principal designer is responsible for all the duties described in the Regulations.

e. The Regulations also require the principal designer to take into account (in addition to construction risks) the health and safety aspects over the whole life of the development. The developer's S38 Application must, therefore, include a management and maintenance plan (in addition to the health and safety file) to demonstrate that the designer has taken the health and safety considerations of future maintenance into account in preparing the design.

f. A management and maintenance plan should include the following items:
   - the type of maintenance activities that are anticipated;
   - the anticipated frequencies of those activities;
   - the estimated duration of those activities;
   - any large plant and equipment required to undertake those activities economically;
   - the estimated costs to complete those activities;
   - a site plan showing maintenance areas, access routes and the locations where maintenance activities are anticipated and
   - a statement describing any secondary function (e.g., recreation area) above or within the SUDS component, and details describing how this function is to be managed and by whom.

g. The principal designer is reminded that any part of the drainage system could be considered a workplace, in accordance with the Regulations.

h. The developer should obtain all necessary statutory consents and other permissions before the agreement is signed. Throughout any pre-application discussions, the developer should be able to show progress in discussions with the relevant bodies. They should be able to show evidence that any conditions will not affect the design of the system. Relevant bodies can include:
   - consent of the pollution control authority (the Environment Agency in England) for emergency overflows and contaminated waters;

- permission of the navigation authority (usually the Canal and River Trust) to discharge to waters under their control;
- permission of riparian owners will be required to discharge to a watercourse;
- landowner's permission to discharge water onto land;
- landowner's permission for construction of any part of the drainage system on third-party land;
- the Crown, Network Rail, airport authorities, or MOD, etc., where special permission may be required for land owned by them;
- the land drainage authority (Environment Agency, for main rivers, local land drainage authorities for non-main rivers) for consent for the construction of outfalls or works within close proximity to a watercourse; or
- English Nature where any of the works will affect an environmentally-designated site (e.g., SSSI) or could affect protected species.

i. Where the developer wishes to connect drainage from streets to a surface water sewer or a combined sewer, they should discuss this with the water company (Thames Water) as early as possible as the specific consent of the water company will be required in advance.

j. The connection of runoff from publicly-adoptable highways to a public sewer is regulated by the Water Industry Act 1991, Section 115. Some water companies may have a separate formal agreement for such discharges. This agreement is formally between the highway authority and the water company but, prior to adoption of the highway, the developer as owner is party to the agreement. Section 115 also deals with connections of surface water to a highway drainage system.

k. It is particularly important to have an agreement in place which confirms the area of highway being drained to the public sewer, especially where there are issues regarding capacity, connection to a combined sewer or where only highway drainage is to be connected to the public sewer.

l. Water companies have no duty to accept land drainage runoff, flows from natural watercourses or groundwater to the public sewer system, and this is not normally permitted.

m. The developer should maintain the integrity of separate surface water sewer systems and is responsible for any blockages, pumping station breakdown, cross-connections, etc., and any impact (e.g., flooding or pollution, etc.) up to the time the sewers are adopted. The developer remains liable for any damages caused by failure of the drainage system until it is formally adopted.

n. The developer should include in their application a plan for approval by the authority to demonstrate how sediment and other debris will be managed to avoid any sediment or debris being discharged into the proposed drainage system, any public sewer or a surface water body. The developer should comply with this plan at all times during construction and during any maintenance carried out prior to adoption.

o. The developer should note that there could be existing public sewers and lateral drains within the site. Due to their nature, historic mapping of these features, particularly former private sewers transferred under Water Industry Act 1991 Section 105A, may not be available and the developer is encouraged to investigate the location and interconnection of any existing drainage assets on site.

p. Where the developer proposes to construct buildings over or near existing public sewers or lateral drains, they should consult the water company at the earliest opportunity. In some cases, the sewer or lateral drain may need to be diverted.

q. As soon as a diversion of an existing public sewer is envisaged as part of the development, the developer should contact the water company to agree if the diversion is feasible. A separate application may be required under Section 185 of the Water Industry Act 1991. It should be noted that since the private sewers transfer, many sewers that were previously private are now public sewers.

r. Where the developer wishes the water company to abandon existing public sewers and lateral drains within their site in accordance with Section 116 of the Water Industry Act 1991, they should contact the water company to agree the required arrangements.

s. Where any works are to be carried out in proximity to existing sewers or lateral drains, appropriate protection methods and mitigation plans should be agreed with the water company to protect the assets. These details should also be retained within the health and safety documents.

2.2. *Surface Water Design principles*

a. The purpose of surface water drainage is to carry water away from buildings and yards and belonging to buildings in a manner that manages flood risk and water quality. Some types of surface water drainage can also enhance amenity and biodiversity. Local authorities can also require surface water drainage systems to meet requirements for flood risk, water quality, amenity and biodiversity.

b. Local authorities have key functions in determining the surface water drainage arrangements as follows:

- as the local planning authority (LPA), they approve the surface water drainage arrangements for new developments and redevelopments in accordance with the National Planning Policy Framework (NPPF), local policies and any supplementary planning documents;
- as the lead local flood authority (LLFA), they provide guidance to the LPA as statutory consultee in all major developments. They may provide advice for other developments;
- as the local land drainage authority (LDA), they regulate any work carried out in or in proximity to non-main rivers (ordinary watercourses) except in areas where there is an internal drainage board.
- The Environment Agency provides guidance to the LPA in areas that are designated critical drainage areas and sites within 20m of a main river as a statutory consultee. It also regulates any work carried out in or in proximity to any main river.
- In some areas there are internal drainage boards which regulate any work carried out in or in proximity to non-main rivers (ordinary watercourses). Where they do not exist, these powers are carried out by the local land drainage authority.
- The NPPF gives an expectation that sustainable drainage systems (SUDS) should be used as first preference in developments of any size. The Ministry of Housing, Communities and Local Government (MHCLG) has also issued practice guidance to support the NPPF in a number of areas.
- The Department for Environment, Food and Rural Affairs (Defra) have also issued Non-statutory Technical Standards for Sustainable Drainage Systems in England. The Local Authorities SUDS Officer Organisation (LASOO)

has also issued practice guidance in relation to both the NPPF and the non-statutory technical standards.
- The designer should submit detailed construction drawings and calculations to show how the proposed design meets the requirements of the local authority, with confirmation of the arrangements for the operation and maintenance of the system in perpetuity.

2.3. Adoption by Water Companies

a. To be capable of adoption by the water company, a component must come within the meaning of a ”sewer” or ”lateral drain” in accordance with the Water Industry Act 1991.

b. This guidance provides the mechanism by which water companies can secure the adoption of a wide range of SUDS components that are compliant with the legal definition of a sewer.

c. Providing a route for adoption allows the four pillars of SUDS design to be properly considered and utilised, with the production of resilient surface water systems that integrate all four. This will enable new development to be more sustainable and deliver a wider range of multi-functional benefits.

d. A component is potentially adoptable as a sewer (or lateral drain) if all of the following apply:
- it is constructed for the drainage of buildings and yards appurtenant to buildings;
- it has a channel (a depression between banks or ridges with a definite boundary);
- it conveys and returns flows to a sewer or to a surface water body or to groundwater; and
- it has an effective point of discharge, which must have lawful authority to discharge into a watercourse or other water body or onto or into land. As with conventional piped systems, this right to discharge must be secured by the developer and transferred to the water company on adoption.

e. Water UK has published a brochure "Sewers for Adoption in England – a changed approach to surface water sewers".

f. The following components are excluded:
- watercourses as defined in law (these include rivers, streams and can include some ditches)
- components built primarily for the drainage of surface water from streets or for the drainage of land;
- components built to manage groundwater;
- components which are part of the structure of a building or yard (e.g., green roof, pervious driveway or guttering and rainwater pipes attached to the building); and
- components which are an integral part of the structure of a street (e.g., a pervious street or the channel formed by the kerb of a conventional road or a channel formed by a depression in the centre of a street).

g. Where surface water sewers are to be adopted by the water company, then this may include all surface water sewers and lateral drains being connected to the surface water sewer, except any that will be adopted by the highway authority or other bodies. The management of other components can be covered by a separate agreement.

h. Some SUDS components are not considered to be adoptable by water companies because they do not meet the conditions set out above. These include pervious pavements, green roofs and filter strips. These components may form part of the drainage design as part of a holistic design provided they are upstream of the adoptable components or form an exceedance flood route.

i. The developer should ensure that any components not adopted by the water company are constructed as designed. They should also make arrangements to ensure their future operation and maintenance in perpetuity. These can include adoption by another body. The developer should provide details of these arrangements in their S104 Application.

j. Where the operation and maintenance of a component managed by another body could adversely impact on the water company's system, an agreement should be in place to protect the water company's system.

k. The designer should take account of the cost of future maintenance activities identified in the maintenance plan as well as the initial capital costs.

l. The local authority can specify requirements for the design of surface water drainage systems that are different to those set out below. The design of the adoptable components should comply with the guidance in this section, in addition to the requirements of the local authority. Where any local authority requirements conflict with the guidance, this should be brought to the attention of the water company at the earliest opportunity.

m. The government guidance to local authorities includes a hierarchy of connection, which can be summarised as follows:
- surface water runoff is collected for use;
- discharge into the ground via infiltration;
- discharge to a watercourse or other surface water body;
- discharge to a surface water sewer, highway drain or other drainage system, discharging to a watercourse or other surface water body;
- discharge to a combined sewer.

n. Where a developer proposes to connect surface water to the existing sewer system they should submit evidence to show how the surface water hierarchy has been applied to the site and why the connection to the sewer is the most practical solution. They should also show that this has been accepted by the LPA and in the cases of major developments, they should also show that this has been reviewed by the LLFA.

o. The location of adoptable drainage components should take account of the need to provide appropriate access to each component for maintenance.

p. The health and safety risks associated with any open water should be assessed and managed in accordance with Chapter 36 of CIRIA Report C753 “The SUDS Manual”. Where the proposed drainage system incorporates any surface components, the design should be carried out in accordance with Chapter 36 of “The SUDS Manual” and a copy of the principal designer's risk assessment should be submitted to the water company.

2.4 Separate Drainage Systems

a. Separate foul and surface water systems should be provided.

b. If, subject to the approval of the local authority, surface water sewers are to discharge into an existing combined (single pipe) sewer system, the separate foul and surface water sewers should be combined at locations immediately upstream of the point where they discharge into the existing combined sewer system. Where there is a risk of the combined sewer surcharging and backing up into the proposed surface water system, a non-return valve should be fitted.

c. The water company has no duty to accept runoff from streets. The developer should note that acceptance of this runoff into the works and, ultimately, the public sewer system, is only by agreement which will not be unreasonably withheld

d. The water company has no duty to accept land drainage runoff, flows from watercourses or groundwater. The developer should note that permission to discharge these flows into the works is not normally given.

2.5 Layout Principles

a. The layout of the development is fundamental to the performance and affordability of the drainage system as well as the wider urban design, including the character of development, amenity, biodiversity, connectivity and the use of the site. Building for Life 12 recommends that designers explore how a holistic approach to design can be taken to the design of sustainable urban drainage by exploiting the topography and geology.

b. Holistic design should work with the topography, existing site features and vegetation to create a harmonious and practical physical and visual layout that integrates various types of access and transport modes (including walking and cycling), drainage, public open space, an attractive street scene and biodiversity within a context of safe and practical design.

c. The location of adoptable drainage components within the system should take account of the needs for access for maintenance.

d. Where maintenance could require the use of a tanker, the access should be suitable for a tanker with a capacity equal to the capacity of the component, up to a maximum of 18,000 litres. The access should include appropriate turning facilities, where necessary.

e. Where in accordance with the maintenance plan access is anticipated to be required for tankers or other maintenance vehicles, an access road with an appropriate surface and rights of way should be provided.

f. Surface water systems should not create a raised reservoir with a capacity in excess of 10,000m^3.

g. Surface water pumping stations should only be used where there is no other practicable method of surface water drainage and an adequate exceedance flood route is provided in the event of failure of the pumping station. Where a developer proposes to construct a surface water pumping station, they should have early discussions with the water company.

2.6 Hydraulic Design

a. The hydraulic design should take account of the requirements of the local authority and the guidance below. The local authority can specify criteria, including design rainfall rates, design flood protection frequencies and allowances, for climate change and urban creep.

b. The hydraulic design should be carried out in accordance with the CIRIA Report C753: The SUDS Manual. The hydraulic design of pipelines and other conduits should be designed in accordance with BS EN 16933-2.

c. Surface water sewer systems should be designed to take the runoff from roofs, yards belonging to those buildings and, subject to the agreement of the water company, the runoff from streets including any flows through pervious pavements where they discharge into the system. For these areas, an impermeability of 100% should be assumed unless it can be demonstrated that the proposed management arrangements will limit the rate of runoff to a lower level. An impermeability of 100% for the whole site area (including soft landscaped areas) should be used in all cases when determining exceedance flows.

d. The water company is not obliged to accept runoff from land drainage or flow from watercourses. In these cases, the developer should agree satisfactory and separate arrangements with the local authority and the water company

e. An appropriate flow simulation method that can simulate flooding from the drainage system should be used for hydraulic design, unless otherwise agreed with the water company. A simple calculation method is likely to be acceptable in the case of small developments.

f. Where a component is designed to convey or store flows in excess of the 1 in 30 year return period event, the designer should demonstrate that the upstream system (including any inlets such as gullies or pervious paving) has the capacity to allow the flows to reach the component.

g. In some cases it is not practical to design a particular component to convey all of the flows necessary (for example, because the infiltration capacity is limited, or the inlets would not have sufficient capacity). In these cases, the additional capacity required to meet the local authority's requirements may be provided using another component or a designated overland flow route (see CIRIA Report C635: Designing for Exceedance in Urban Drainage - Good Practice). Where an overland flow route is used, it should not be designed to operate more frequently than in a 1 in 30 year return period design rainfall event.

2.7 Control of Surface Water Discharges from the Site.

a. The local authority can impose restrictions on the method of discharge of surface water from a development on the rate and volume of discharge. They can also specify the frequency and duration(s) of the design rainfall used to calculate the discharge, including any allowance for climate change and urban creep.

b. Where storage is provided to control surface water discharges from the site, the designer should demonstrate that:

- the upstream system (including the inlets) has sufficient capacity to deliver the design flows to storage, either in its entirety or in combination with overland flow pathways
- an overland flow pathway is provided that will safely manage any exceedance flows

c. The design of storage should take into account the frequency and extent of any surcharge in the downstream system, including flood levels at any discharge point into a watercourse, lake or pond.

2.8 Drainage Components on the Surface and Infiltration Systems

a. The capacity of surface level components (e.g., swales, ponds and basins) is not normally constrained by the capacity of the inlet system in the same way as underground components. They may, therefore, be designed to accept higher flow rates than underground drainage systems up to the 1 in 100 year rainfall event plus climate change standard typically required by local authorities.

b. Provided there is provision for the flows to reach a particular feature, surface SUDS features designed to take 1 in 100 year rainfall event plus climate change will normally be adoptable.

c. Components that are designed to be filled with water intermittently (e.g. basins or swales) should be designed so that the water is apparent at least a few times a year to ensure that the public are aware of their function. Where appropriate, signage should be provided to indicate:

- that the area can be filled with water; and
- to describe the flood risk management function of the component.

d. Further guidance on the hydraulic design of surface drainage components, including appropriate hydraulic roughness values can be found in Chapters 3 and 24 of the CIRIA Report C753: The SUDS Manual.

e. Guidance on the hydraulic design of infiltration drainage components can be found in Chapter 25 of the CIRIA Report C753: The SUDS Manual.

f. The infiltration potential of the soil and subsoil used in the hydraulic design of infiltration components should be confirmed by geo-technical tests, taking account of the seasonal variation in groundwater conditions. Guidance on this can be found in Chapter 25 of the CIRIA Report C753: The SUDS Manual. The highest groundwater level should be at least 1m below the base of the proposed infiltration component.

g. On sloping sites, the impact of the infiltration on neighbouring land should be taken into account.

2.9 Underground Drainage Components

a. Underground drainage systems include piped sewers and drains, and underground attenuation storage tanks.

b. The Colebrook-White hydraulic roughness value (k_s) for surface water sewer and lateral drain pipe design should be 0.6mm.

c. Underground drainage pipes should be designed under pipe full conditions to accept the following design rainfall (i.e., without surcharging above pipe soffit):

- sites with average ground slopes greater than 1% 1 year;
- sites with average ground slopes 1% or less 2 year; and
- sites where consequences of flooding are severe 5 year. (e.g., existing basement properties adjacent to new development)

d. The capacity of pipe should be increased further where it is necessary to comply with the flooding protection requirements.

e. The capacity of inlets to the systems (e.g., gullies or pervious paving systems) can limit the flows that can enter underground drainage systems. Gully systems designed in accordance with the Design Manual for Roads and Bridges (HA 102/17) will not admit all the flows from streets into an underground system during extreme events (e.g., 1 in 100 years). Where the design of the system requires that flows from rainfall events in excess of the capacity of the gully systems are conveyed or stored in an underground system, the designer should use alternative inlets systems with higher capacity.

2.10 Exceedance Flow Management

a. During exceptionally wet weather, in excess of the design conditions specified by the local authority, the capacity of the surface water drainage system can be inadequate and flooding can occur. Surface water drainage system components should be located so as to minimise the risk of damage to buildings or other critical infrastructure in the event of sewer flooding.

b. Flooding can also occur due to blockages, pumping station failure or surcharging in downstream sewers.

c. In designing the site sewerage and layout, developers should identify the flow paths and understand the potential effects of flooding. They should then design flood exceedance routes to mitigate its impact, where practicable. Guidance of design of flood exceedance routes can be found in CIRIA Report C635: Designing for Exceedance in Urban Drainage – Good Practice.

2.11 Sediment Management

a. Urban roads generate more sediment than rural roads, approximately 200g/m^2/year. Sediment can typically reduce pipe capacity by about 4%.

b. An effective means of sediment control should be provided within the drainage system and particularly upstream of any attenuation component (e.g., pond, wetland, basin or tank), infiltration component, filtration component or outfall. Around 90g/m^2/year is retained in gully pots.

c. The sediment control system should not only capture sediment under low flows but ensure that sediment is not re-entrained and washed out under peak flow conditions. In urban roads, sediment concentration is around 115mg/litre and sediment size is typically 0.5mm.

d. Sediments can be controlled by various means including catch-pits, hydrodynamic vortex separators and (in ponds, wetlands, basins and bio-retention systems) by use of a sediment forebay. An effective means of sediment control should be provided within the drainage system upstream of any attenuation component (e.g., pond, wetland, basin or tank), infiltration component, filtration component or outfall.

e. Sediment management components should incorporate access to and into the component for removal of accumulated sediment. This should include provision of appropriate vehicular access to facilitate removal. The operations and maintenance plan should describe procedures for sediment removal.

f. Where there is any risk of sediment entering an underground tank, provision should be made for removal of the sediment. See drawings LBS500/10 and LBS500/11.

2.12 Infiltration Components

a. In almost all cases, infiltration drainage components can be constructed in proximity to buildings without any detrimental impact on building foundations. However, in some ground conditions problems can occur particularly, where the infiltration is concentrated in a small area.

b. BS 6297 2007 [Ref 4.I] sets a minimum depth of 1.2m between the base of an infiltration trench and the seasonally highest groundwater level.

c. Where infiltration is proposed within 5m of foundations of any buildings or other structures, this should be agreed with a geotechnical specialist who is the designer of the foundations of the building or structure.

d. The local authority can impose requirements to prevent pollution of groundwater from polluted surface water.

2.13. Pipe System Layout

a. Surface water sewers and lateral drains should not normally be constructed under any building or any structure except that they may cross under a boundary wall not greater than 1.8m high. However, for terraced properties it is sometimes necessary to install intermediate rainwater pipes, along the length of the terrace, to take rainwater from more than one property. Where it is not reasonably practicable to route the sewer around the building, surface water sewers with a nominal internal diameter of no more than 100mm may be laid under a building, provided that the sewer takes the drainage from no more than one rainwater pipe with a nominal internal diameter of no more than DN75, or the equivalent cross-sectional area, provided that the entry point to the rainwater pipe is in the land owned by the building concerned. Where such a solution is proposed for adoption, it should be discussed with the water company at the earliest stage.

b. Access points, and any inlets to drains or sewers, should be located so as to minimise the risk of damage to buildings or other critical infrastructure in the event of sewer flooding.

c. The minimum size for a gravity surface water sewer should be 225mm nominal internal diameter.

d. The minimum size for a gravity surface water lateral drain (connections to gully pots) should be 150mm nominal internal diameter.

e. To provide a self-cleansing regime within surface gravity sewers, the minimum flow velocity should be 1m/second at pipe full flow. Where this requirement cannot be met, then this criterion would be considered to be satisfied if:
   - a 150mm nominal internal diameter gravity sewer is laid toa gradient not flatter than 1:150; or
   - a 100mm nominal internal diameter lateral drain is laid to a gradient not flatter than 1:100.

f. These parameters should not to be taken as a norm when the topography permits steeper gradients. Hydraulic studies indicate that these requirements may not necessarily achieve a self-cleansing regime. When a choice has to be made between gravity sewerage and pumped sewerage, these criteria should not be regarded as inflexible and the developer should consult the water company. See drawing LBS500/01.

2.14. Swales and Rills

a. A swale is a shallow, vegetated channel designed to convey and retain water but may also permit infiltration.

b. Where a swale is adopted it will usually include the sides and base of the channel, any vegetation that is part of the function of the swale and any under-drainage including any liner, check dam, flow control or erosion control measure.

c. The design of swales should be carried out in accordance with Chapter 17 of the CIRIA Report C753: The SUDS Manual.

d. Swales proposed for adoption should typically be located in verges or other public open space or on the boundary between the street and a private garden. Where they are not adjacent to a street, provision should be made for access by maintenance equipment.

e. A rill is a small, shallow lined channel through which surface water can flow.

f. Where a rill is adopted it will usually include the material forming the sides and base of the channel and any check dam or flow control device.

g. Rills proposed for adoption should typically be located in verges or other public open space or on the boundary between the street and a private garden. Where they are not adjacent to a street, provision should be made for access by maintenance equipment.

2.15. Bioretention Systems (or Rain Gardens)

a. A bioretention system is a shallow planted depression that allows runoff to pond temporarily on the surface, before filtering through vegetation and underlying soil prior to collection or infiltration. In its simplest forms, it can be a tree pit or a rain garden. Engineered soil (gravel and sand layers) and enhanced vegetation can be used to improve treatment performance.

b. The channel is formed by the banks of the depression. The effective point of discharge may take the form of a properly designed means of infiltrating the water into the ground below or an overflow to another sewer.

c. Where a bioretention system is adopted, it will usually include the whole area used for temporary ponding of water and the inlet and outlet structures and any engineered soil structures, including the vegetation.

d. Detailed design should be carried out in accordance with Chapter 18 of CIRIA Report C753: The SUDS Manual.

e. Bioretention systems should be designed to drain down within 24 hours.

2.16. Ponds, Wetlands and Basins

a. A pond is a permanently wet depression designed to temporarily store surface water runoff above the permanent pool.

b. A wetland is a type of pond with a high proportion of shallow zones that promote the growth of bottom-rooted plants.

c. The channel is formed by the depression between the banks of the pond or wetland.

d. Where ponds are adopted, this will usually include the inlet and outlet structures (including flow controls) and the entire area of the pond, including any banks that are designed to retain water, any storage below the ground surface, impermeable liners and under drains.

e. The maximum water level in any pond should be at least 500mm below the lowest floor level of any adjacent properties.

f. The maximum design storage depth should give a freeboard of 600mm below the top of the banks.

g. Design should be carried out in accordance with Section 23 of the CIRIA Report C753: The SUDS Manual.

h. Where wetlands are used for flow attenuation, the depth of temporary storage above the permanent water level should be limited so that the risk to plant damage is low.

i. A basin is a depression in the ground that is normally dry but is designed to store surface water before infiltration (infiltration basin) and/or to provide attenuation (detention basin).

j. The effective point of discharge can be a properly-designed means of infiltrating the water into the ground. The channel will be formed by the depression or between the banks of the basin.

k. Where basins are adopted, this should usually include the inlet and outlet structures (including flow controls) and the entire area of the basin including any banks that are designed to retain water, any storage below the ground surface, impermeable liners and under drains.

l. Design should be carried out in accordance with Chapter 22 of the CIRIA Report C753: SUDS Manual.

m. The maximum water level in any basin shall be at least 500mm below the lowest floor level of any adjacent properties.

n. The maximum design storage depth should give a freeboard of between 400mm and 600mm below the top of the banks, depending on the scale of the component.

o. Infiltration basins should be provided with an inlet flow spreader to distribute flows across the basin, ideally using a widening grass channel inlet. The base should be level across the basin to encourage even infiltration with a slight fall of between 1 in 100 and 1 in 200 along the basin to distribute water evenly.

2.17. Tanks

a. A tank is an underground structure that creates a void space for the temporary storage of surface water before infiltration, controlled release or use.

b. Tanks should have provision for access for inspection and cleaning. This should include a means of removing any sediment and a means of trapping sediment to prevent it from being washed downstream during cleaning operations.

c. The structural design of geocellular tanks should be carried out by a person competent to do so using the guidance, in CIRIA Report C737: Structural and Geotechnical Design of Modular Geocellular Drainage Systems or other established engineering principles. Verified product performance data should be used for the engineer to make their assessment.

d. The design of flow attenuation facilities should, wherever practicable, include the following criteria:
   - gravity tank sewers or tanks formed from oversized pipes should be designed as online storage;
   - where parallel pipes are used for attenuation, a minimum of one pipe should act as online storage, the remainder as offline;
   - the design of attenuation facilities should seek to prevent a build-up of silt and other debris (e.g., by use of benching and low-flow channels).

e. Adequate ventilation should be provided to limit pressure build up in the system during filling. The means of ventilation should be agreed with the highway authority.

2.18. Infiltration trenches & Filter Drains

a. An infiltration trench is a trench, usually filled with permeable granular material, designed to promote infiltration of surface water to the ground.

b. A filter drain is a linear drain consisting of a trench filled with a permeable material, normally with a perforated pipe in the base of the trench to assist drainage.

c. Design should be carried out in accordance with Chapter 13 of CIRIA Report C753: The SUDS Manual.

d. Infiltration trenches and filter drains should be designed with a perforated pipe (or other suitably-defined inspection channel) along the whole length and adequate access chambers to provide access for inspection and maintenance. See drawing LBS500/02.

2.19. Soakaways

a. A soakaway is a subsurface structure for the temporary storage of water before it soaks in to the ground. A soakaway is essentially a point feature; it does not have a channel.

b. To be considered for adoption, a soakaway must be fed by an upstream channel that is legally a sewer or lateral drain that is also proposed for adoption.

c. A commuted sum may be required to offset the renewal of the soakaway once it has become silted up after 20 years, say.

d. Soakaways are not generally permitted in Southwark because of the general impermeability of the underlying London clays. They will require a level 1 departure.

e. Where a soakaway is adopted, this will usually include the whole structure up to the external face, including any external rubble fill or membrane.

f. Soakaway chambers shall be formed by excavation of a pit to the required depth.

g. The base of the excavation for the soakaway chamber shall be fitted with a concrete footing.

h. The sides of the soakaway chamber shall be lined. The lining of the soakaway chamber may comprise cast in situ segmental concrete or precast perforated concrete rings or slabs.

i. Brickwork or blockwork can be used to line soakaway chambers, but it is unlikely to be suitable for larger soakaways used on principal roads.

j. A typical design for a soakaway chamber utilising precast concrete rings is provided in CIRIA C753 [Ref 14.N].

k. The concrete footing and chamber lining shall be porous to permit the outward discharge of water.

l. The areas between the sides of the excavation and the chamber lining shall be backfilled with aggregate or other suitable material.

m. Based on guidance provided in CIRIA C753 [Ref 14.N] the backfill can comprise, for example, Type B filter material identified in MCHW Series 500 [Ref 9.N] or selected granular material in accordance with Class 6H of Table 6/1 of MCHW Series 600 [Ref 10.N].

n. The soakaway chamber shall include a cover and inspection hatches in accordance with CD 534 [Ref 2.I] and MCHW Series 500 [Ref 9.N].

o. Unlined pit soakaways shall be filled to the surface with well graded granular material, free of fines in accordance with Class 6G of Table 6/1 of MCHW Series 600 [Ref 10.N].

p. The granular material provides support to the pit sides to prevent collapse as well as ensuring there is no void which could form a significant safety hazard.

q. Fill materials used in pit type soakaways typically have porosity values in the range 20-40%. The porosity of the fill material needs to be known for the hydraulic design calculations in accordance with BRE DG 365 [Ref 12.N]

r. Granular materials used for backfill and for unlined pits shall exclude constituents that could result in leaching of harmful substances into the underlying groundwater.

s. Filled pits and chambers shall include an inspection well.

t. Guidance in BS EN 752 [Ref 5.I] suggests the use of a 225 mm perforated pipe as an inspection well in filled soakaways.

u. The design of trench type soakaways shall include inspection tubes (observation wells) at regular intervals.

v. In considering the requirements for access, this should include provision of access for removal and replacement of any fill material.

2.20. Outfall Structures

a. Surface water outfalls discharging to watercourses should be fitted with non-return valves, where necessary, to prevent backflow in the event of high water levels in the watercourse.

b. Design should be carried out in accordance with Chapter 28 of the CIRIA Report C753: The SUDS Manual.

c. A hinged, lockable safety grille should be fitted to any surface water outfall pipe that is 350mm diameter or larger. Where necessary, the outfall should be angled to reduce the risk of bank erosion.

d. Access should be provided for cleaning and maintenance of the grille, and for inspection of the outfall.

e. The design of the outfall can be subject to the approval of the local land drainage authority.

2.21. Flow Control Devices

a. The design and location of flow control devices are to be agreed with the highway authority.

b. Design should be carried out in accordance with Chapter 28 of the CIRIA Report C753: The SUDS Manual.

c. The design of flow control devices should, wherever practicable, include the following features:

- flow controls may be static (such as vortex flow controls or fixed orifice plates) or variable (such as pistons or slide valves);
- where debris can enter the control (e.g., where the upstream system is open or where the inlets are gullies), static controls should have a minimum opening size of 100mm, or equivalent;
- where the design of the upstream system will prevent debris entering the system (e.g., underground systems where the inlets are pervious pavement systems), static controls should have a minimum opening size of 50mm;
- variable controls may have a smaller opening provided they have a self-cleansing mechanism;
- a bypass should be included with a surface operated penstock or valve; and
- access should be provided to the upstream and downstream sections of a flow control device to allow maintenance.

d. All flow control devices should be installed and operating before off-site discharge is made.

e. Flow control devices should have a free discharge (no downstream surcharge), where practicable. Where it is not practicable to achieve a free discharge at all times, attenuation calculations showing both the free discharge and surcharge conditions should be provided as part of the S38 Application.

2.22. Proprietary Treatment Systems

a. Where treatment devices are installed on discharges from locations which have a high pollution hazard level (as defined in Table 26.2 of the CIRIA Report C753: The SUDS Manual) any treatment device should be part of the private drainage system, or the street drainage system, as appropriate.

b. Where the developer proposes to include a proprietary treatment device as part of the system proposed for adoption, they should consult the highway authority at the earliest opportunity.

2.23. Landscaping and Vegetation

a. In addition to any requirements of the local authority, landscape design and vegetation should be in accordance with Chapter 29 of the CIRIA Report C753: The SUDS Manual.

b. A management plan setting out the management objectives of the landscaping and vegetation, and an initial management programme for at least the first five years, should be included in the overall management plan submitted with the S38 Application

2.24. Materials

a. Materials and components should comply with the following:
   - the manufacturing process should minimise the use of solvent-based substances that emit volatile organic compounds or ozone-depleting substances;
   - products should be made from recycled material, where reasonably practicable; and
   - the use and/or creation of substances included in the UK Red List (DoE, 1988) of toxic substances should be avoided during the manufacturing process.

2.25. Construction

a. SUDS components should be constructed in accordance with CIRIA Report C768: Guidance on the Construction of SUDS.

b. A construction method statement, prepared in accordance with Part E of CIRIA Report C768: Guidance on the Construction of SUDS should be submitted by the developer for approval.

c. The works should be protected, where necessary, from loads imposed by construction plant during construction to avoid the over compaction of soils that could increase runoff from permeable areas and adversely affect the infiltration qualities of sub-soil layers.

d. The developer should carry out a survey of the completed drainage system and produce as-constructed drawings. These should be cross-checked with the design drawings and any variations not previously agreed should be highlighted.

2.26. Maintenance

a. A management plan setting out the management objectives of the scheme and an initial programme should be submitted with the Section 38 Application to demonstrate that the systems can be economically maintained and that appropriate access for maintenance has been provided. Additionally, long- and medium-term strategies should be outlined as part of any submission.

b. Soft SUDS components will require regular, occasional or remedial maintenance so a simple establishment maintenance plan for the first 5 years should be provided. However, planting, wetlands and biodiverse (wild flower) grasslands in particular will require an over-arching management plan that defines how it is expected that the vegetation will develop over time, and what it seeks to achieve (in line with the 4 pillars of SUDS). This should be defined through a simple vision statement, supported by appropriate management aims and objectives.

c. The management plan should require the quality and condition of the SUDS to be reviewed every 5 years, and a new maintenance plan devised for the forthcoming 5 year period that understands the dynamic nature of the soft SUDS, and adjusts the maintenance regime as necessary to ensure their long-term development and effectiveness.

d. The management plan should be in accordance with Chapter 32 of the CIRIA Report C753: The SUDS Manual. It should detail:
  - regular maintenance activities;
  - occasional maintenance activities; and
  - remedial maintenance activities.

e. The management plan should detail the type of maintenance activities required, the frequency of those activities, the estimated duration, plant and equipment requirements and estimated costs.

f. The management plan should show how appropriately-sized maintenance plant can be routed to avoid over-compaction of areas that are required to allow infiltration.

3 Spacing of Road Gullies

3.1. Rule of Thumb Guide

a. *A* general guide is that each gully should not drain more than 200m^2 impermeable area and this can be relied on for small maintenance schemes.

b. The spacing of road gullies should be between 40m and 50m apart. However in low areas, or where the carriageway gradient is flat, this spacing should be reduced to 25m to 30m.

c. The correct spacing of road gullies for larger schemes should be determined in accordance to the DMRB CD 526 Rev3, Spacing of Road Gullies (formerly HA102/17). See drawings LBS500/12 and LBS500/13.

3.2. Allowable Flow Width

a. The flow of water parallel to the kerb shall not exceed an allowable flow width (see Figure 1 below).

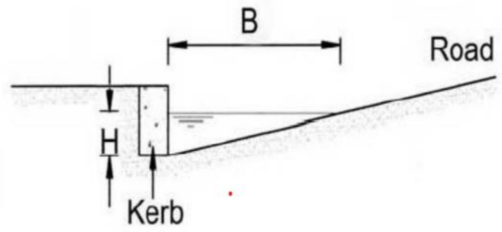


Figure 1 Flow width of water against kerb.

b. When checked for a 1 in 5 year storm, the allowable flow width B shall not exceed 500mm for roads in Southwark (as specified in the Highway Policy Plan) because an excessive flow width can be a danger to traffic and spray from vehicles can drench pedestrians.

c. The grating of the gully or kerb inlet shall collect as much of the approaching flow as possible. Efficiency η (%) is expressed as the water flow down the grating or inlet as a percentage of the approaching flow (Figure 2 below).

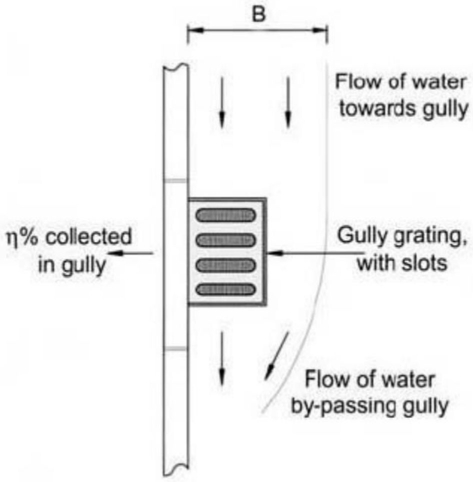


Figure 2. Flow of water along kerb and by-passing gully grating

d. Any water not collected flows past the grating, augmenting the flow in the next downstream section. No flow shall bypass a terminal gully. The overall hydraulic capacity of a system of road gratings and kerb inlets shall capture any water that by-passes any single grating in the system.

3.3. Types of Gully Grating

a. Gully gratings shall comply with the requirements outlined in BS EN 124 [Ref 2.N].

b. The hydraulic capacity of a gully grating depends on its overall size, the number and orientation of the slots and the total waterway area provided by the slots.

c. Gully gratings shall be rectangular or triangular with one side adjacent to the kerb

d. The kerb face of the frame should be hard against the kerb.

e. The portion of the total waterway area within 50mm of the kerb should not be less than 45cm^2, in accordance with BS 7903 [Ref 5.I].

f. The hydraulic design method in this document assumes that the gap between the kerb and the first slot(s) of a gully grating is not greater than 50mm.

g. Circular gully gratings, and any shapes that are highly asymmetric in a direction transverse to the kerb, shall not be used.

h. Grating slots shall be orientated so as not to pose a hazard to cyclists riding over them in the direction of travel. BS EN 124 [Ref 2.N] allows grating slots parallel to the kerb which can present a serious hazard to cyclists.

i. Classification of gratings shall be determined by the method of calculation in Section 3.5 below, based upon the geometric characteristics of the grating.

j. In order to deal with the large number of possible designs that can be produced, Section 3.5 below sets out a method of classifying gratings based on their hydraulic characteristics - Types P, Q, R, S or T in decreasing hydraulic capacity. The advantage of this approach is that a grating type can be specified during design, ensuring the required hydraulic performance whatever type of conforming grating is chosen during construction.

k. If a manufacturer wishes to carry out hydraulic tests to determine the classification of a grating, a suitable test procedure is described in HRW SR 533 [Ref 7.I].

l. Where a gully grating is under performing hydraulically, it may be more cost effective to install a more efficient grating than install an additional gully.

3.4. Factors affecting Hydraulic Design

a. The hydraulic parameters of channels, gratings and inlets shall be evaluated in accordance with this section before commencing the design procedure.

b. An initial assumption about the most suitable grating type (P to T) for a particular scheme shall be made, and upgraded if it does not prove satisfactory.

c. The Manning roughness coefficient of the channel (n) shall be taken as no less than 0.017 for an asphalt surface. Values for Manning's n for different drainage channel materials are given in Table 1 below.

Surface	**Condition**	**Manning's n**
Concrete	Average	0.013
Concrete	Poor	0.016
Asphalt	Average	0.017
Asphalt	Poor	0.021

Table 1. Values of Manning's n

d. The location of specific gullies shall first be fixed by the requirements and advice given in this section.

e. The location and spacing for any intermediate gullies may be determined by the design methods given in Sections 3.6 and 3.7 below.

f. Calculations shall commence at the crests or highest point of the scheme and proceed downhill.

g. Design storm return periods are given in DMRB CG 501 [Ref 1.N].

3.4.1 Effect of Performance reduction

a. A performance factor 'm' shall be included to allow for reduced grating efficiency.

b. Reduced efficiency can be caused by the accumulation of debris that reduces the hydraulic area and therefore the efficiency.

c. The performance factor m has a value of 1.0 for no effect, and decreasing values for increasing levels of risk.

d. Values for m are given in Table 2 below.

e. Site specific characteristics can determine the grating efficiency factor m to be used in the design.

Situation	**Maintenance Factor (m)**
Baseline condition	1.0
Roads subject to substantial leaf falls or vehicle spillages (e.g. at sharp roundabouts)	0.8
Sag points on road gradients	0.7

Table 2. Values of performance factor.

3.4.2 Types of Gully

a. The type of gully, intermediate or terminal, shall be determined by the distinction between their two modes of hydraulic operation.

b. Intermediate gullies are those for which some calculated proportion of the approaching flow can be permitted to continue past the gully, to be picked up by the next gully downstream as shown in Figure 2. This is known as by-pass flow.

c. Terminal gullies are those for which no significant proportion of the approaching flow is permitted to pass the gully, either because there is no downstream gully or because the passing flow will interfere with traffic.

d. Gully design shall allow future maintenance to be carried out safely and effectively.

e. Gully design shall not affect the safety of cyclists and other road users and will not impact upon traffic flow.

f. Gullies shall be located so as not to pose a hazard to users of pedestrian, cycle or equestrian crossings.

g. Gullies shall be located so that there is no standing water at pedestrian, cycle or equestrian crossings.

h. A particular problem occurs at sag points in gradients, both because floating debris will tend to accumulate at this point, and because any water not entering a gully at this point cannot pass to another gully.

i. Where the crest along a length of road with changing longitudinal gradient is well defined, a gully is not required at this point.

j. Where there is a slow transition from negative to positive gradient, a gully may be placed at the crest to prevent any ponding of water.

k. In cases such as the following it can be beneficial to install an additional upstream gully, designed to act as a terminal gully:

- Transitions to superelevations.
- A pedestrian, cycle or equestrian crossing.
- For steeply angled road junctions.

3.4.3 Rainfall

a. The design rainfall intensity I (mm/hr) shall be determined in accordance with the requirements described in DMRB CG 501 [Ref 1.N].

b. It must be noted that the design rainfall intensity should be increased by 20% to allow for the potential effects of Climate Change.

c. Design rainfall intensity may also be determined from the formula given in CD 521 [Ref 3.N], reproduced below:

$$I = 32.7(N - 0.4)^{0.223}\left\{(T - 0.4)^{0.565}\frac{2\min M5}{T}\right\}$$

Eqn. 1. Rainfall intensity.

d. The term 2minM5 describes the depth of rainfall (in mm) falling at a site over a period of 2 minutes, and with an average return period of 5 years (i.e. an annual exceedance probability of 20%). This is a measure of the rainfall characteristics at any given site and is reproduced in Figure 4 in Appendix A.

e. Design values of the storm return period N are given in CG 501 [Ref 1.N].

f. Records indicate East Anglia and the South East experience lower Average Annual Rainfall than other parts of the UK. However, these regions experience higher intensity and more frequent short duration storms, particularly during summer months as demonstrated by the 2minM5 values shown in Figure 4.

g. The critical storm duration T (in minutes) is the time of concentration of flow for the area served by the gully.

h. The critical storm duration T used for simple modelling purposes is generally recognised as 5 minutes.

i. T can be significantly less than 5 minutes for gullies spaced at less than 10m intervals, and with moderate to severe longitudinal gradients (more than 4%).

j. T can be significantly greater than 5 minutes for gullies spaced at greater than 50m intervals, and with flatter longitudinal gradients (less than 0.5%).

k. The value of T shall be checked for the shortest and longest drainage lengths between gullies.

l. The sum of the time taken for water to travel from the furthest point on the road surface to the kerb, t_s, and then along the kerb to the gully, t_g, should be approximately equal to T, i.e.:

$$T = t_s + t_g$$

Eqn.2. Critical storm duration

m. A value of t_s of 3 minutes is generally recommended.

n. For a reasonably uniform gradient, t_g (in minutes) can be calculated from the flow velocity, V (in m/s) and gully spacing (*Sp*):

$$t_g = \frac{Sp}{60V}$$

Eqn.3. Time to flow allow the kerb to gully

$$V = \frac{2Q}{B^2 Sc}$$

Eqn.4. Flow velocity.

o. If Equation 2 shows T to be outside the range 4 to 7 minutes, the design procedure should be repeated using the recalculated value of critical storm duration (T) rounded to the nearest minute.

3.4.4 Catchment Width

a. All paved areas draining to the kerb shall be included in the catchment width.

b. Paved areas can include hard shoulders, paved central reserves, footways, emergency refuge areas and maintenance hard-standing. Roof drainage from buildings can also be included where it discharges to road gullies.

c. The effective catchment width draining to the kerb channel, W_e (in m), may be determined from a plan area of the site.

d. If the unpaved area exceeds the paved area then the methodology outlined in CD 521 [Ref 3.N] shall be used to determine the effective catchment width draining to the kerb channel.

e. Where the unpaved area does not exceed the paved area, it may be accepted that runoff contribution from unpaved areas equates to 20% that of an equivalent paved area.

3.5. Determining the Grating Type

a. When determining the grating type, the following three geometrical properties are determined first:

- The area A_g (in m^2) of the smallest rectangle parallel to the kerb that just includes all the slots.
- The waterway area as a percentage (p) of the grating area A_g.
- The coefficient C_b determined from Table 3 below.

b. Bars more than 10mm below the surface of the grating are treated as part of the waterway area when calculating the value of *p*. If a grating has a combination of bar alignments, the number of transverse slots and the number of slots with other alignments are calculated. If there are more transverse slots than other slots, C_b is be taken as 1.75; otherwise C_b is taken as 1.5.

Grating Bar Pattern	**C_b**
Transverse bars	1.75
Other bar alignments (i.e. longitudinal, diagonal and bars curved in plan)	1.5

Table 3. Grating bar pattern

c. The category into which a grating falls may then be determined from the value of the grating parameter G (in s/m^2):

$$G = \frac{69C_b}{(A_g^{0.75})\sqrt{p}}$$

Eqn. 5. Grating Parameter

d. The grating type and the corresponding design value G_d of the grating parameter is then determined from Table 4 below. The value of G_d should be used to calculate the maximum spacing between gullies, rather than the actual value of G from Equation 5.

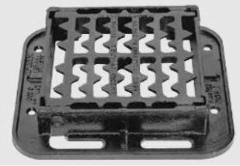
Grating type	Range of G (s/m^2)	Design value G_d (s/m^2)
P	<30	30
Q	30.1 – 45	45
R	45.1 – 60	60
S	60.1 – 80	80
T	80.1 - 110	110

Table 4. Determination of grating type.

Type P grating.

Type Q grating.

Type R grating.



Type S grating.

Type T grating.

3.6. Use of Table to Determine the Flow Capacity of Gullies

a. A design table (Table 6) is given in Appendix B of this document. This can be used, subject to the limitations indicated, to determine gully spacings with the minimum of calculation.

b. Alternatively the equations on which they are based are given in Section 3.7 below and these equations can be used directly.

c. It should be noted that the tables refer to spacing of intermediate gullies. The design of terminal gullies is described at the end of this section.

3.6.1 Hydraulic Parameters

a. The following parameters are required:

- Values of the longitudinal gradient, S_L, at points along the length of the scheme (expressed as fractions in the design tables and calculations). For an individual length drained by a gully, S_L should be taken as the average gradient over a 3m distance upstream of the gully.
- The cross-fall, S_c, also expressed as a fraction in the tables and calculations. It is measured 0.5m upstream of the leading edge of the gully and for the maximum permissible width of flow.
- The Manning roughness coefficient, n.
- The maximum allowable flow width against the kerb is 0.5m in Southwark (see B in Figure 2).
- The grating type (P, Q, R, S or T).

b. Table 6 can be used to determine the discharge at the kerb immediately upstream of the grating if required. For intermediate values of cross-fall and gradient, the flow may be either interpolated or taken as the nearest higher value. For values of n other than 0.017, the flow should be multiplied by 0.017/n.

3.6.2 Maximum Spacings for Gully Gratings

a. Table 6 in Appendix B gives the area of road that may be drained (A_{dr} in m^2) by an intermediate gully for a rainfall intensity of 50mm/hr, performance factor m = 1.0, and n = 0.017 for each of grating types P to T. The actual area (A_a) that can be drained is then given by:

$$A_a = A_{dr}(50/I)mk_n$$

Eqn. 6. Actual area that can be drained.

b. It is sufficiently accurate, where the grating efficiency η at n = 0.017 is more than about 80%, to set k_n to 0.017/n. The exact solution is:

$$k_n = \left(\frac{\left(\frac{0.017}{n}\right) - \left(\left(1-\left(\frac{\eta}{100}\right)\right)\left(\left(\frac{0.017}{n}\right)^2\right)\right)}{\frac{\eta}{100}} \right)$$

Eqn. 7. Determination of k_n.

c. The maximum design spacing between adjacent intermediate gratings (S_p in m) is then given by:

$$S_p = A_a/W_e$$

Where We is the Effective Catchment Width
Eqn. 7. Maximum design spacing between intermediate gratings.

d. Table 6 also gives the flow collection efficiency η of the grating in %. If η is below about 60%, the grating is not very efficient, and the design should be reconsidered (see Section 3.7). The design method is intended to be applied over a range of η between 100% and 50%. Below 50%, it becomes increasingly conservative.

e. Table 6 is for intermediate gullies on a uniform gradient, and become inaccurate for gradients which vary greatly over short distances. As a general guide, errors become significant if the gradients between adjacent gullies change by more than two of the increments in the tables, and also if the grating efficiency η is less than 80%. A more accurate calculation for this case is given in Section 3.7.

3.6.3 Terminal Gullies

a. The procedure for designing different arrangements of terminal gullies is as follows:

- Single gully at sag point. There will be flow into the gully from both directions. Table 6 or Equation 12 in Section 3.7 are used to determine which direction gives the greater flow. This flow is then doubled, and Equation 12 is used to determine the flow collection efficiency η. For effective drainage this is greater than 95%. The maximum allowable spacings upstream of the gully is then checked using Equation 13 or 14.
- Twin gullies at sag point (the more efficient arrangement, possibly requiring fewer gullies upstream). Use Table 6 or the equations to determine the design spacing and η for each gully. η will be greater than 95% for both gullies.
- Other terminal gullies (where it is not desirable for the flow to bypass the grating) The design spacing upstream of the gully should be determined from the Tables 6 or the equations. To avoid excessive flow past the gully, η should be greater than 95%.

3.7. Use of Equations for Determining the Flow Capacity of Gullies

This section describes the equations used in the design procedure described in this document. They were used in compiling the design table 6 and may also be used for direct calculation of gully spacings. These equations may readily be programmed, and in this form are very easy to use for exploring the effects of changing the drainage parameters.

3.7.1 Flow Capacity of Kerb Channel

a. The water depth against the kerb (H, in m) as shown in Figure 2 is given by:

$$H = BS_c$$

Where B = 0.5m in the Borough of Southwark
Eqn. 8. Water depth against kerb.

b. The cross-sectional area of flow, A_f (in m^2), just upstream of the grating is given by:

$$A_f = BH/2$$

Eqn. 9. Cross-sectional area of flow.

c. The hydraulic radius of the channel, R (in m), is given by:

$$R = \frac{A_f}{H + \sqrt{B^2 + H^2}}$$

Eqn. 10. Hydraulic radius of channel.

d. The flow rate, Q (in m^3/s) approaching the grating is calculated from Manning's equation:

$$Q = \frac{A_f R^{\frac{2}{3}} S_L^{\frac{1}{2}}}{n}$$

Eqn. 11. Flow rate.

3.7.2 Flow Collection Efficiency of Gully Grating

a. The flow collection efficiency, η (in %) is given by:

$$\eta = 100 - G_d\left(\frac{Q}{H}\right)$$

Where Gd is the grating parameter and its value is determined by the grating type - see Section 3.5.
Eqn. 12. Flow collection efficiency.

b. The acceptable range of values for η is discussed in Section 3.6.2.

3.7.3 Maximum Design Spacing of Gully Gratings

a. For intermediate gratings along a uniform longitudinal gradient, the maximum allowable spacing between adjacent gratings (S_p) may be calculated from the equation:

$$S_p = \frac{\left(3.6 \cdot 10^6 Q \frac{m\eta}{100}\right)}{W_e I}$$

Eqn. 13. Maximum allowable spacing.

b. For non-uniform gradients, the grating spacings are calculated going downstream for each pair of gratings, and Equation 13 is replaced by:

$$S_p = \frac{3.6 \cdot 10^6 \left[Q - Q_{us}\left(1 - \frac{m_{us}\eta_{us}}{100}\right)\right]}{W_e I}$$

Eqn. 14. Non-uniform allowable spacing.

c. Where Q_{us}, m_{us} and η_{us} refer to the upstream grating. Calculations using this equation should commence at the upstream end. If the upstream end is at the top of a crest with no gully, Q_{us} becomes zero.

3.7.4 Effect of Longitudinally Varying Gradient

a. If the longitudinal gradient of a kerb channel increases significantly with distance in the direction of flow, it is necessary to check that the channel has sufficient flow capacity at all points along its length. If the distance between two adjacent gullies is Z and the gradient at the downstream gully is S_L as described in Section 3.6, then at any intermediate distance Z_i from the upstream gully the local gradient S_i should satisfy the following requirement:

$$S_i > S_L \left(\frac{Z_i}{Z}\right)^2$$

Eqn. 15. Check on longitudinally varying gradient.

b. If the limit is not satisfied, an additional gully should be located at the point where the kerb channel has insufficient capacity.

c. Note that the limit only needs to be checked if S_i increases with Z_i, the opposite of what might be expected. The above requirement is independent of whether gratings or kerb inlets are used.

3.7.5 Flow Capacity of Gully Pots

a. On steeper sections of road, the maximum allowable spacing between gullies may not be determined by the collection efficiency of the grating but by the flow capacity of the gully pot beneath it.

b. Experimental tests in HRW SR 508 [Ref 6.I] indicate that the maximum flow rate that can be accepted by a gully pot without surcharge is about 10 litres/s if the outlet pipe has a diameter of 100mm, and 15 litres/s if it has a diameter of 150mm. Table 6 in Appendix B gives estimated discharges at the kerb, under a rainfall intensity of 50 mm/hr, for combinations of flow width, crossfall and longitudinal gradient.

3.7.6 Redesign

a. The design gully spacings determined from Table 6 in Appendix B or by calculation are the maximum spacings: good practice would aim to reduce this distance. If the design shows the gully spacing or grating efficiency to be inadequate for the scheme, then redesign using one or more of the following options.

- If the grating efficiency η is less than about 80% for an intermediate gully, the most effective solution is likely to be redesign with an improved grating type.
- If the grating efficiency η of a terminal grating is less than 95%, redesign is essential. The first step should be to redesign with an improved grating type. If the required efficiency is still not achieved, the permitted width of kerb flow B should be replaced by a lesser design width. This will have the effect of reducing the design flow approaching the grating and increasing the

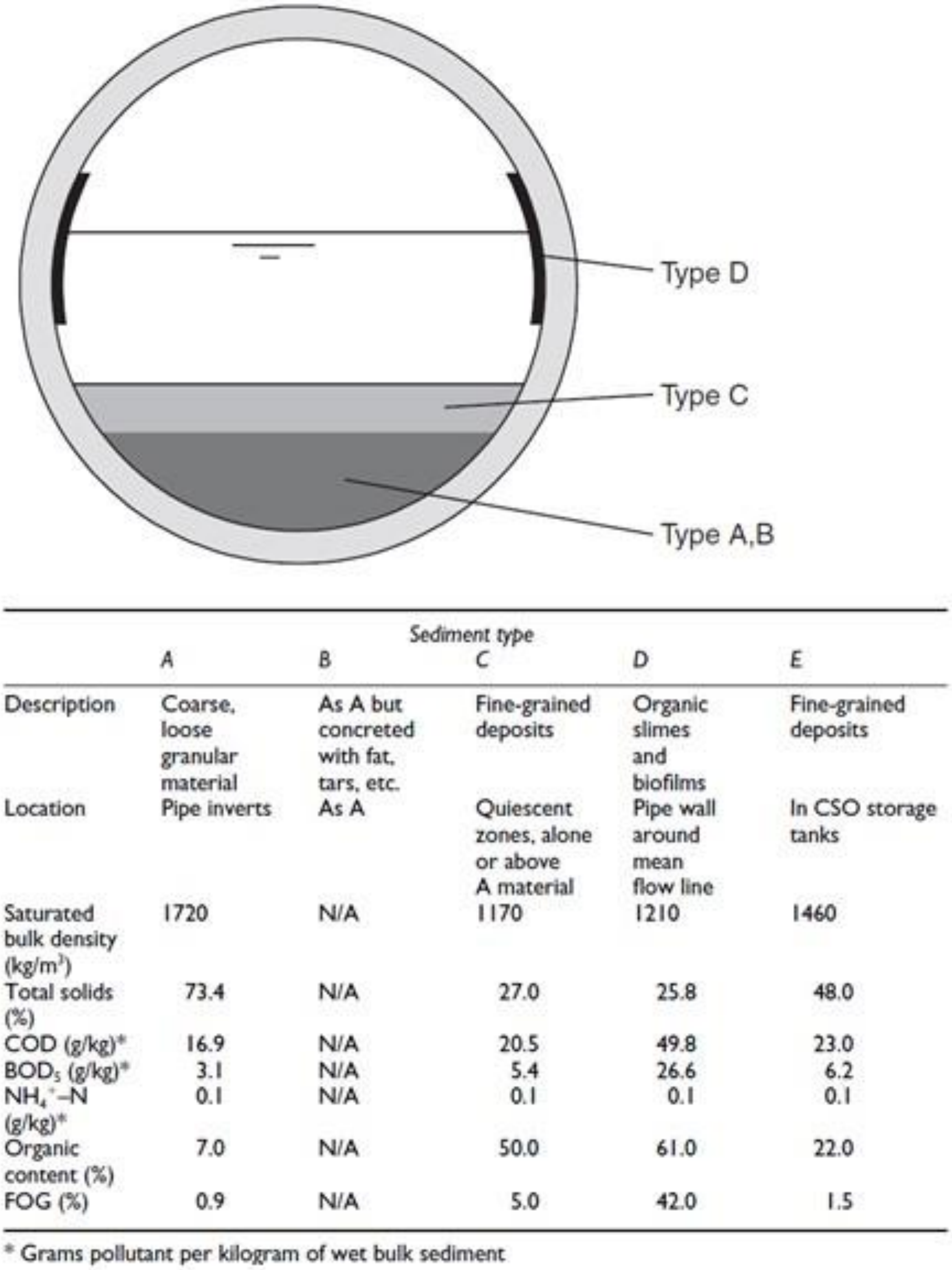
grating efficiency, but may require the use of additional intermediate gullies.

b. Alternatively it may be more practical to adjust other parameters, e.g. changes in the road profile or the catchment width.

3.8. Pipe Gradients, Capacity and Self Cleansing Flow

3.8.1 Sediment and Self Cleansing Flow

a. The main types of sediment found in drainage systems are illustrated in figure 3 below.



	Sediment type				
	A	B	C	D	E
Description	Coarse, loose granular material	As A but concreted with fat, tars, etc.	Fine-grained deposits	Organic slimes and biofilms	Fine-grained deposits
Location	Pipe inverts	As A	Quiescent zones, alone or above A material	Pipe wall around mean flow line	In CSO storage tanks
Saturated bulk density (kg/m^3)	1720	N/A	1170	1210	1460
Total solids (%)	73.4	N/A	27.0	25.8	48.0
COD (g/kg)*	16.9	N/A	20.5	49.8	23.0
BOD_5 (g/kg)*	3.1	N/A	5.4	26.6	6.2
NH_4^+–N (g/kg)*	0.1	N/A	0.1	0.1	0.1
Organic content (%)	7.0	N/A	50.0	61.0	22.0
FOG (%)	0.9	N/A	5.0	42.0	1.5

* Grams pollutant per kilogram of wet bulk sediment

Figure 3. Main types of sediment found in drainage systems.

b. All drainage pipes will handle a certain amount of small sediments which enter the pipe with the runoff. This sediment will usually settle within the pipe and must be cleared to avoid the pipes flow capacity reduced and eventually becoming blocked. The best way to remove these sediments is to allow the drained water to clear the pipe during storm events, rather than rely on expensive regular jetting or other maintenance activities.

c. A drain is considered to be self-cleansing when there is a balance in the rate of deposition and erosion in the pipe which maintains a suitable depth of sediment. The depth of sediment should not reach levels where the capacity of the pipe is significantly affected or where maintenance efforts are required.

d. In order to achieve this, drainage pipes must be designed for the water to flow at self-cleansing velocities. The water must flow fast enough to transport small sediments in suspension, to move coarser material along the pipe invert and to erode any deposits which form on the pipe invert during periods of low flow such as during prolonged dry weather for storm drains.

e. This self-cleansing velocity is often stated as a requirement in national standards. The requirements for a drain to be self-cleansing however can be a complex calculation as it depends on the pipe diameter, runoff and sediment characteristics and flow rates patterns.

f. For preliminary and small scale design there are a number of standard minimum velocities and gradients which have been proposed. Many standards and publications simply advise that a minimum velocity is allowed for at a particular flow rate. BS EN 16933-2 states that small diameter drainage pipes less than 300mm diameter can be designed with either a velocity of 0.7m/s daily, or that the pipes should be laid at a gradient steeper than the pipe diameter, ie a 150mm pipe should be laid at a gradient of at least 1 in 150.

g. Surface water drains up to 900mm diameter should be designed for a minimum velocity of 1.0m/s in pipe full conditions. Sewers for Adoption similarly recommends a value of 1.0m/s at full flow for storm sewers and a minimum velocity of 0.75m/s at one third design flow for foul sewers.

h. Table 5 below gives Badwin Latham experimental results for self-cleansing flow in different pipe diameters:

Diameter of sewer (mm)	Minimum self-cleansing velocity (m/s)
150 - 250	1.00
300 - 600	0.75
> 600	0.60

Table 5. Badwin Latham's self-cleansing flow velocities.

3.8.2 Scouring Velocity

a. Higher flow velocities can move the sediments at sufficient speeds to erode and damage the internal diameter of the drainage system over time.

b. To avoid reaching this scouring velocity it recommended that the maximum flow velocity in a drainage design is less than or equal to 3m/s.

3.8.3 Pipe Capacity

a. The capacity of drainage pipes varies with the size, gradient, and material the pipe is made from. If the pipe is completely full is discharge is less than if it is 90% full as the air in the top of the pipe reduces friction and allows faster flow.

b. Detailed design can determine the capacity, but for easy reference, Figure 6 in Appendix C describes general pipe capacities (in litres/second) for various gradients and pipe diameters (in inches).

3.8.4 Pipe Velocity and Discharge According to Manning's Equation

a. Circular pipes used for storm water collection systems design is generally based on the Manning model (Manning 1891), where the flow section is mostly partially filled. The manning formula is commonly used in practice and is assumed to produce the best results when properly applied.

b. The usage of Manning's model assumes the flow to be steady and uniform, where the slope, cross-sectional flow area and velocity are not related to time and are constant along the length of the pipe being analysed.

c. The Manning formula used to model free surface flow can be written as follows:

$$Q = \frac{1}{n} R_h^{2/3} \; A S^{1/2}$$

Eqn. 16. Manning's discharge for a pipe.

or

$$V = \frac{1}{n} R_h^{2/3} S^{1/2}$$

Eqn. 17. Manning's velocity for a pipe.

Where:

Q = Flow rate (m^3/sec)

R_h = Hydraulic radius (m)

n = Pipe roughness coefficient (Manning's n) (sec/m^3)

A = Cross sectional flow area (m^2)

S = Slope of pipe bottom, dimensionless

V = Flow velocity (m/sec)

d. Equations 16 and 17 can be written as functions of the water surface angle shown in figure 4 below.

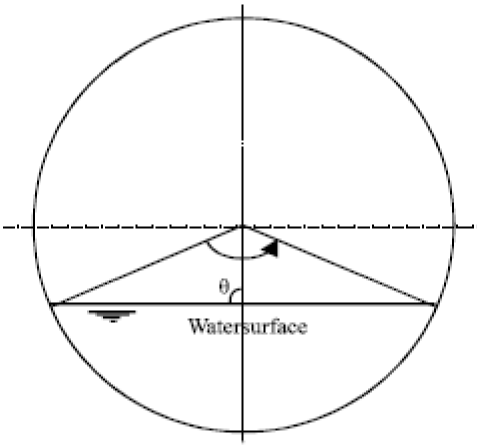


Fig. 4. Water surface angle

$$Q = \frac{1}{n}\left(\frac{D^8}{2^{13}}\right)^{1/3} \left[\frac{(\theta - \sin\theta)^5}{\theta^2}\right]^{1/3} S^{1/2}$$

Eqn. 18. Manning's velocity for a pipe

$$V = \frac{1}{n}\left(\frac{D}{4}\right)^{2/3} \left[\frac{(\theta - \sin\theta)}{\theta}\right]^{2/3} S^{1/2}$$

Eqn. 19. Manning's velocity for a pipe

$$A = \frac{D^2}{8}(\theta - \sin(\theta))$$

Eqn. 20. Cross sectional flow area (m^2)

$$P = \theta\frac{D}{2}$$

Eqn. 21. Wetted perimeter (m)

$$R_h = \frac{A}{P} = \frac{D}{4}\left(1 - \frac{\sin(\theta)}{\theta}\right)$$

Eqn. 21. Hydraulic radius (m)

Where:

D = Pipe diameter (m)

r = Pipe radius:

$$r = \frac{D}{2} \; (m)$$

Eqn. 22. Pipe radius (m)

P = Wetted perimeter (m)

θ = Water surface angle (Radian)

e. Equations 18 and 19 for known values of flow Q, roughness n, slope S and diameter D can be solved only after a series of long iterations.

Appendix A – Rainfall Depth

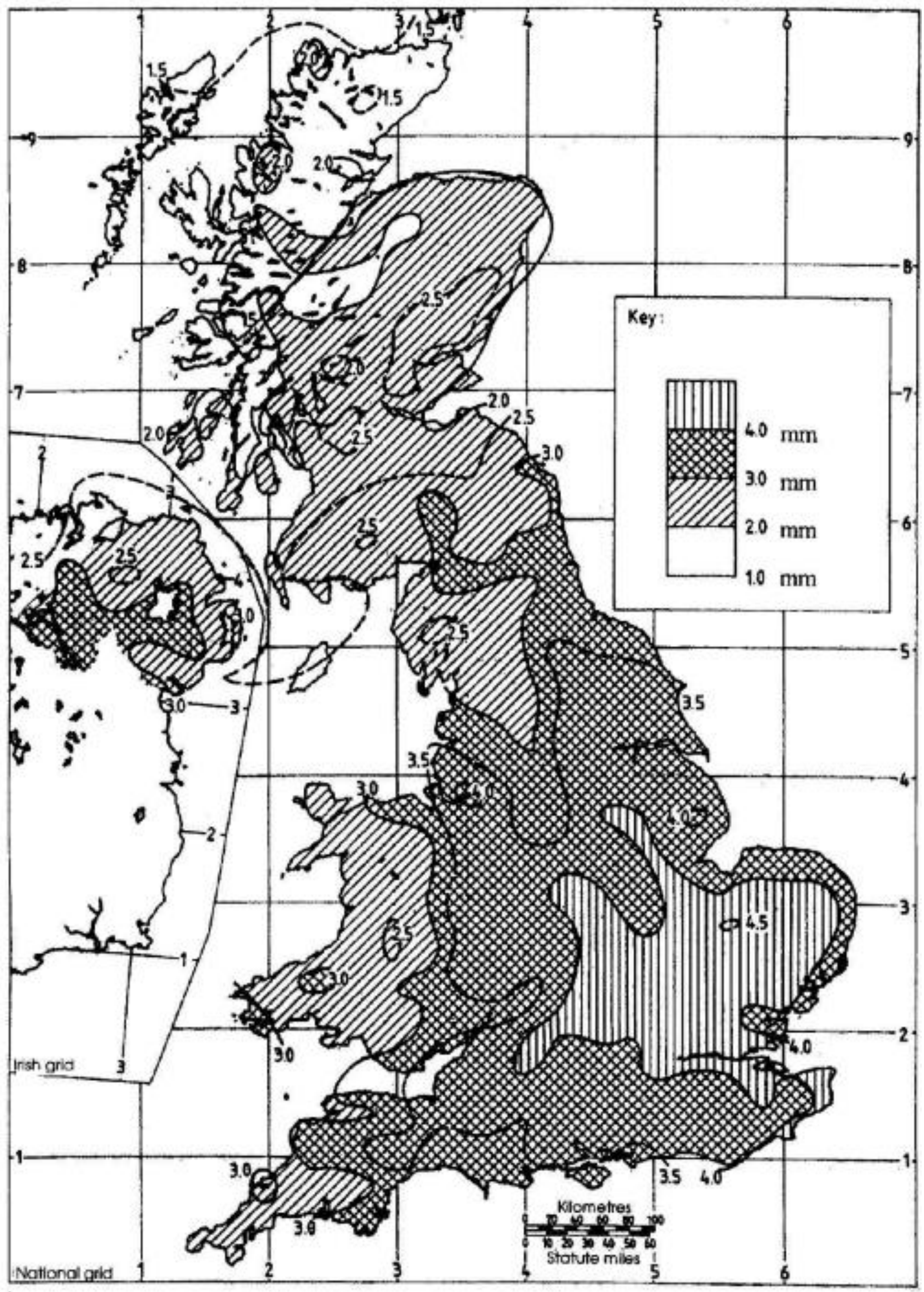


Figure 4. Values of 2minM5 rainfall depth for the UK (reproduced from BS 6367 Ref.1 (now BS EN 12056 Ref.4).

Appendix B – Table of Discharge at the Kerb in litres/second for a Flow Width of B = 0.5m.

Crossfall % (S_c)	Gradient % (S_L)	Discharge Litres/sec	Type P		Type Q		Type R		Type S		Type T	
			Drained area of road m^2	Collection efficiency (%)	Drained area of road m^2	Collection efficiency (%)	Drained area of road m^2	Collection efficiency (%)	Drained area of road m^2	Collection efficiency (%)	Drained area of road m^2	Collection efficiency (%)
1/60 (1.67%	1/300 (0.33%)	0.18	13	99	13	99	13	-	13	98	13	98
	1/150 (0.67%)	0.26	18	99	18	99	18	-	18	98	18	97
	1/100 (1.0%)	0.31	22	99	22	98	22	-	22	97	22	96
	1/80 (1.33%)	0.35	25	99	25	98	25	-	24	97	24	95
	1/60 (1.67%)	0.41	29	99	29	98	28	-	28	96	28	95
	1/50 (2.0%)	0.44	31	98	31	98	31	-	31	96	30	94
	1/40 (2.5%)	0.50	35	98	35	97	34	-	34	95	33	93
	1/30 (3.33%)	0.57	40	98	40	97	40	-	39	94	38	92
	1/20 (5.0%)	0.70	49	97	49	96	48	-	47	93	46	91
	1/15 (6.67%)	0.81	57	97	56	96	55	-	54	92	52	89
1/50 1/50 (2.0%)	1/300 (0.33%)	0.24	19	99	17	99	17	-	17	98	17	97
	1/150 (0.67%)	0.35	25	99	25	98	24	-	24	97	24	96
	1/100 (1.0%)	0.42	30	99	30	98	30	-	30	97	29	95
	1/80 (1.33%)	0.47	34	99	33	98	33	-	33	96	32	95
	1/60 (1.67%)	0.55	39	98	38	98	38	-	38	96	37	94
	1/50 (2.0%)	0.60	42	98	42	97	42	-	41	95	40	93
	1/40 (2.5%)	0.67	47	98	47	97	46	-	46	95	45	93
	1/30 (3.33%)	0.77	54	98	54	97	53	-	52	94	51	91
	1/20 (5.0%)	0.95	66	97	65	97	64	-	63	92	61	90
	1/15 (6.67%)	1.10	76	97	75	95	74	-	72	91	69	88
1/40 (2.5%)	1/300 (0.33%)	0.35	25	99	25	99	25	-	25	98	25	97
	1/150 (0.67%)	0.50	36	99	35	98	35	-	35	97	34	96
	1/100 (1.0%)	0.61	44	99	43	98	43	-	42	96	42	95
	1/80 (1.33%)	0.69	49	98	48	98	48	-	47	96	46	94
	1/60 (1.67%)	0.79	56	98	55	97	55	-	54	95	53	93
	1/50 (2.0%)	0.87	61	98	61	97	60	-	59	94	58	92
	1/40 (2.5%)	0.97	68	98	67	97	67	-	65	94	64	91
	1/30 (3.33%)	1.12	78	97	77	96	78	-	75	93	73	90
	1/20 (5.0%)	1.37	96	97	94	95	92	-	90	91	87	88
	1/15 (6.67%)	1.58	110	96	108	94	105	-	102	90	98	86

Table 6. Discharge at the kerb in litres/second for a flow width of B=0.5m.

Table of Discharge at the kerb in litres/second for a flow width of B=0.5m (continued).

Crossfall % (S_c)	*Gradient % (S_L)*	*Discharge Litres/sec*	*Type P*		Type Q		Type R		Type S		Type T	
			Drained area of road m^2	*Collection efficiency (%)*	*Drained area of road m^2*	*Collection efficiency (%)*	Drained area of road m^2	*Collection efficiency (%)*	Drained area of road m^2	*Collection efficiency (%)*	Drained area of road m^2	*Collection efficiency (%)*
1/30 (3.33%	*1/300 (0.33%)*	*0.57*	*41*	*99*	*40*	*98*	*40*	*-*	*40*	*97*	*39*	*96*
	1/150 (0.67%)	*0.80*	*57*	*99*	*57*	*98*	*56*	*-*	*56*	*96*	*55*	*95*
	1/100 (1.0%)	*0.99*	*70*	*98*	*69*	*97*	*68*	*-*	*68*	*95*	*66*	*93*
	1/80 (1.33%)	*1.10*	*78*	*98*	*77*	*97*	*76*	*-*	*75*	*95*	*74*	*93*
	1/60 (1.67%)	*1.27*	*89*	*98*	*88*	*97*	*87*	*-*	*86*	*94*	*84*	*92*
	1/50 (2.0%)	*1.39*	*98*	*97*	*97*	*96*	*95*	*-*	*94*	*93*	*91*	*91*
	1/40 (2.5%)	*1.56*	*109*	*97*	*107*	*96*	*106*	*-*	*104*	*93*	*101*	*90*
	1/30 (3.33%)	*1.80*	*125*	*97*	*123*	*95*	*121*	*-*	*118*	*91*	*114*	*88*
	1/20 (5.0%)	*2.20*	*152*	*96*	*149*	*94*	*146*	*-*	*142*	*89*	*136*	*85*
	1/15 (6.67%)	*2.54*	*175*	*95*	*171*	*93*	*166*	*-*	*161*	*88*	*152*	*83*
1/50 *1/25 (4.0%)*	*1/300 (0.33%)*	*0.77*	*55*	*99*	*54*	*98*	*4*	*-*	*54*	*97*	*53*	*96*
	1/150 (0.67%)	*1.09*	*77*	*98*	*76*	*98*	*76*	*-*	*75*	*96*	*73*	*94*
	1/100 (1.0%)	*1.33*	*94*	*98*	*93*	*97*	*92*	*-*	*91*	*95*	*89*	*93*
	1/80 (1.33%)	*1.49*	*105*	*98*	*103*	*97*	*102*	*-*	*101*	*94*	*98*	*92*
	1/60 (1.67%)	*1.72*	*120*	*97*	*119*	*96*	*117*	*-*	*115*	*93*	*112*	*91*
	1/50 (2.0%)	*1.88*	*132*	*97*	*130*	*96*	*128*	*-*	*125*	*92*	*121*	*90*
	1/40 (2.5%)	*2.10*	*147*	*97*	*144*	*95*	*142*	*-*	*139*	*92*	*134*	*88*
	1/30 (3.33%)	*2.43*	*168*	*96*	*165*	*95*	*162*	*-*	*158*	*90*	*151*	*87*
	1/20 (5.0%)	*2.97*	*204*	*96*	*200*	*93*	*195*	*-*	*189*	*88*	*179*	*84*
	1/15 (6.67%)	*3.43*	*234*	*95*	*228*	*92*	*222*	*-*	*213*	*86*	*200*	*81*
1/20 (5.0%)	*1/300 (0.33%)*	*1.11*	*79*	*99*	*78*	*98*	*78*	*-*	*77*	*96*	*76*	*96*
	1/150 (0.67%)	*1.56*	*110*	*98*	*109*	*97*	*108*	*-*	*107*	*95*	*105*	*93*
	1/100 (1.0%)	*1.92*	*135*	*98*	*133*	*97*	*132*	*-*	*129*	*94*	*126*	*92*
	1/80 (1.33%)	*2.14*	*150*	*97*	*148*	*96*	*146*	*-*	*144*	*93*	*140*	*91*
	1/60 (1.67%)	*2.47*	*173*	*97*	*170*	*96*	*167*	*-*	*164*	*92*	*159*	*89*
	1/50 (2.0%)	*2.71*	*189*	*97*	*186*	*95*	*182*	*-*	*178*	*91*	*172*	*88*
	1/40 (2.5%)	*3.03*	*210*	*96*	*206*	*95*	*202*	*-*	*197*	*90*	*189*	*87*
	1/30 (3.33%)	*3.50*	*241*	*96*	*236*	*94*	*231*	*-*	*224*	*89*	*213*	*85*
	1/20 (5.0%)	*4.28*	*293*	*95*	*285*	*92*	*277*	*-*	*266*	*86*	*250*	*81*
	1/15 (6.67%)	*4.95*	*335*	*94*	*324*	*91*	*314*	*-*	*300*	*84*	*279*	*78*

Table 6 continued. Discharge at the kerb in litres/second for a flow width of B=0.5m.

Table of Discharge at the kerb in litres/second for a flow width of B=0.5m (continued).

Crossfall % (S_c)	*Gradient % (S_L)*	*Discharge Litres/sec*	*Type P*		Type Q		Type R		Type S		Type T	
			Drained area of road m^2	*Collection efficiency (%)*	*Drained area of road m^2*	*Collection efficiency (%)*	Drained area of road m^2	*Collection efficiency (%)*	Drained area of road m^2	*Collection efficiency (%)*	Drained area of road m^2	*Collection efficiency (%)*
1/15 (6.67%	*1/300 (0.33%)*	*1.77*	*125*	*98*	*124*	*98*	*123*	-	*122*	*96*	*120*	*94*
	1/150 (0.67%)	*2.50*	*176*	*98*	*174*	*97*	*172*	-	*169*	*94*	*165*	*92*
	1/100 (1.0%)	*3.06*	*214*	*97*	*211*	*96*	*208*	-	*204*	*93*	*198*	*90*
	1/80 (1.33%)	*3.42*	*239*	*97*	*235*	*95*	*231*	-	*226*	*92*	*218*	*89*
	1/60 (1.67%)	*3.95*	*274*	*96*	*269*	*95*	*264*	-	*257*	*91*	*247*	*87*
	1/50 (2.0%)	*4.33*	*299*	*96*	*293*	*94*	*287*	-	*279*	*90*	*267*	*86*
	1/40 (2.5%)	*4.84*	*333*	*96*	*326*	*93*	*318*	-	*308*	*88*	*293*	*84*
	1/30 (3.33%)	*5.59*	*382*	*95*	*372*	*92*	*362*	-	*348*	*87*	*328*	*82*
	1/20 (5.0%)	*6.84*	*462*	*94*	*447*	*91*	*432*	-	*412*	*84*	*381*	*77*
	1/15 (6.67%)	*7.90*	*528*	*93*	*508*	*89*	*488*	-	*461*	*81*	*420*	*74*

Table 6 continued. Discharge at the kerb in litres/second for a flow width of B=0.5m.

Derived from research see HRW SR 533 (Ref 7.1)
Manning's Coefficient is n = 0.017
For other values of Manning's n, multiply the discharge by (0.017/n).
Drained area of road in m^2 under a rainfall intensity of I = 50mm/hour.
For other values of rainfall intensity I, multiply the area by (50/I).

Appendix C – Pipe Capacity in litres/second for Various Gradients and Diameters

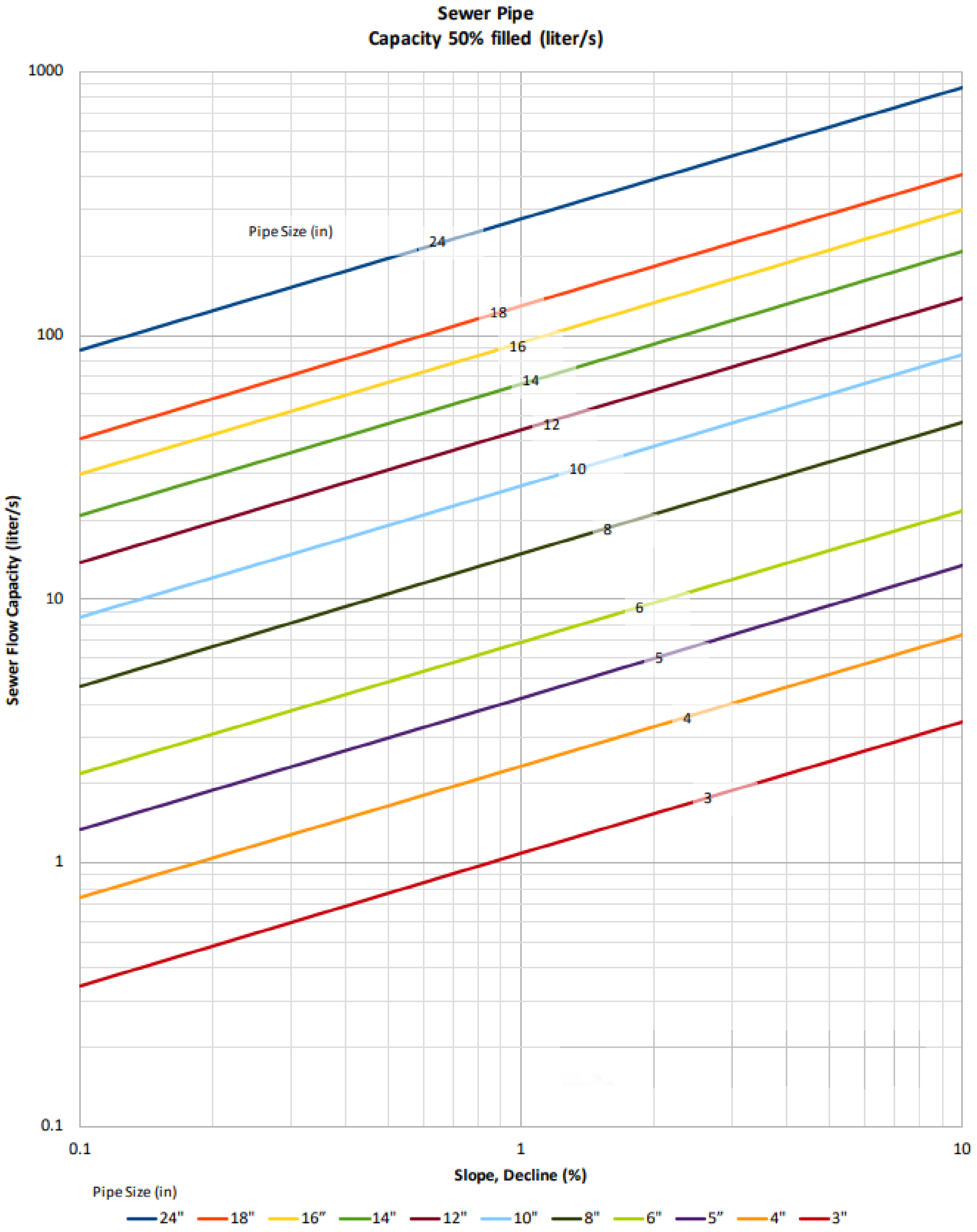


Figure 5. Pipe Capacity in litres/second for Various Gradients and Diameters.