BRE Connect Online

Spending hours searching for construction information?

You don't need to

Get unrivalled knowledge from BRE, the UK's world-leading built environment experts.

BRE Connect Online gives you instant and unlimited access to over 1700 authoritative BRE publications.

Find out what BRE Connect Online can do for you.

CALL US NOW
+44 (0) 1344 328038

What do you get?

All new and published BRE titles

700 books, reports and guides
– research, innovation, best practice and case studies, including best-sellers:

- Recognising wood rot and insect damage in buildings
- Building on fill
- Roofs and roofing
- The Green Guide to Specification

250 Digests
– authoritative state-of-the-art reviews

600 Information Papers
– BRE research and how to apply it in practice

150 Good Building and Repair Guides
– Illustrated practical guides to good building and repair work

And much more...

What's new in 2016

More than 30 new titles, including:

- Cracking in buildings (new edition)
- Technology for automated BIM checking
- Energy efficient refurbishment
- Building elements: walls, windows and doors (new edition)

BRE Group (BRE) is a world-leading centre of built environment expertise, research and training, and includes a third-party approvals organisation offering certification of products and services to international markets
BRE, Garston, Watford WD25 9XX
Tel: +44 (0) 333 321 8811
Email: enquiries@bre.co.uk, www.bre.co.uk

BRE is owned by **BRE Trust**, the largest UK charity dedicated specifically to research and education in the built environment. BRE Trust uses the profits made by BRE to fund new research and education programmes that advance knowledge, innovation and communication for public benefit

IHS (NYSE: IHS) is the leading source of information, insight and analytics in critical areas that shape today's business landscape. Businesses and governments in more than 165 countries around the globe rely on the comprehensive content, expert independent analysis and flexible delivery methods of IHS to make high-impact decisions and develop strategies with speed and confidence. IHS is the exclusive publisher of BRE publications

IHS Global Ltd is a private limited company registered in England and Wales (no. 00788737). Registered office: Willoughby Road, Bracknell, Berkshire RG12 8FB. www.ihs.com.

Digests are authoritative summaries of the state of the art on specific topics in construction design and technology. They draw on BRE's expertise in these areas and provide essential support for all involved in design, specification, construction and maintenance

BRE publications are available from www.brebookshop.com or IHS BRE Press, Willoughby Road, Bracknell, Berkshire RG12 8FB. Tel: +44 (0) 1344 328038, Fax: +44 (0) 1344 328005, Email: brepress@ihs.com

DG 365, February 2016
ISBN 978-1-84806-918-6

DG 365
Revised 2016

Digest

Soakaway design

Stephen L Garvin

Digest 365 is one of the most widely used BRE publications, aiding designers to support planning and development applications. This edition of Digest 365 describes the design and construction procedures for soakaways, and explains how to calculate rainfall design values and soil infiltration rates. It also gives useful examples of how to design soakaways.

This revised edition includes important changes to recommendations and requirements which have been introduced since the last edition was published in 2007.

1 Introduction

Digest 365 on soakaway design was first published in 1991, replacing Digest 151. Digest 365 is widely used by designers to support planning and development applications.

This revised edition includes a number of important changes, including the following:

- recommendations by The Environment Agency on predicted climate change effects
- data on a return period of 100 years
- description of sustainable drainage systems (SUDS)
- flood management
- updated illustrations and new references
- glossary.

This revised edition retains the fundamental approach included in previous editions – the content has been updated rather than rewritten. However, the revision will ensure that Digest 365 remains fit for purpose.

This Digest describes design and construction procedures for soakaways, explains how to calculate rainfall design values and soil infiltration rates, and gives examples of designing soakaways. It provides data to facilitate designs for 10- to 100-year rainfall events (note that regulatory requirements may not be as onerous as 100-year events).

A traditional way of disposing of surface water from buildings and paved areas, soakaways are used remotely from a public sewer or watercourse. However, in recent years, soakaways have been used within urban, fully sewered areas to limit the impact on discharge of new upstream building works and to avoid the cost of upgrading sewers outside building developments. Increasingly soakaways are seen as a more widely applicable option alongside other means of surface water control and disposal in sustainable drainage.

Soakaways are used to store the immediate surface water run-off from hard surfaced areas, such as roofs or car parks, and allow for efficient infiltration into the adjacent soil. They discharge their stored water sufficiently quickly to provide the necessary capacity to receive run-off from a subsequent storm. The time taken for discharge depends upon the soakaway shape and size, and the surrounding soil's infiltration characteristics.

Soakaways can be square, circular (conventional), or trench excavations. They can be filled with rubble, lined with brickwork, plastic cells, perforated pre-cast concrete ring units or any similar structure that collects rainwater and run-off. The structures are built to allow rainwater to infiltrate directly into the ground. Soakaways can also be deep bored.

There are times when a soakaway may not be an appropriate solution, eg in areas of ground that have low permeability, where surface water could be contaminated. The maximum seasonal water table should be above the base of the soakaway; contaminants in the ground could be mobilised, or in areas of instability.

Although the guidance in this Digest can inform design and construction of soakaways, further specialist advice will be required.

2 Design and construction considerations

2.1 General

Soakaways can provide a long-term, effective method of disposal of surface water from impermeable areas of several hundred square metres. Long-term maintenance and inspection must be considered during the design and construction process. For wet well soakaways, vehicle-mounted suction emptying and jetting equipment can be used, so suitable access to inspection covers must be provided.

Risk of pollution to the quality of groundwater must be considered. Roof surface run-off should not cause damage to groundwater quality and may be discharged directly to soakaways. Those pollutants entering the soakaway from roofs tend to remain in the soakaway, or in its immediate environs, attached to soil particles. However, paved surface run-off for larger trafficked areas should be passed through a suitable form of oil interception device prior to discharge to the soakaway.

Maintenance of silt traps, gully pots and interceptors will improve the long-term performance of soakaways. The use of wet well chambers within the soakaway system can further assist in pollutant trapping and extending the operating life of soakaways.

Care must be taken so that the introduction of large volumes of surface run-off into the soil does not disrupt the existing sub-surface drainage patterns; it may be advantageous to use extended trench-type soakaway systems. The effect of ground slope must be considered when siting soakaways to avoid waterlogging of downhill areas.

Soakaways should not normally be constructed closer than 5 m to building foundations. In chalk, or other soil and granular fill subject to modification or instability, the advice of a specialist geo-technologist should be sought as to the advisability and siting of a soakaway.

Site investigations must be undertaken thoroughly and competently so that all aspects of soil properties, geo-technology and hydrogeology are adequately reviewed alongside the hydraulic designs of soakaways.

2.2 Sustainable drainage

Sustainable drainage is a departure from the traditional piped approach to draining sites. Sustainable Drainage Systems (SUDS) mimic natural drainage through:

- storing run-off rainwater and releasing it slowly (attenuation)
- allowing water to soak into the ground (infiltration)
- slowly transporting (conveying) water on the surface
- filtering out pollutants
- allowing sediments to settle out by controlling the flow of water.

Soakaways are one of the key technologies for SUDS. They enable stormwater to be dealt with at source rather than being diverted directly into the sewer system; they also satisfy the criteria listed in the bullet points above.

Soakaways can be used on their own or as part of a larger SUDS development. Considering SUDS at the earliest stages of site selection and design makes it easier to integrate them into developments. SUDS can influence other aspects of the site (ie design, layout and function). Reducing impermeable areas wherever possible is also important.

A useful concept used in the development of SUDS is the SUDS management train. The SUDS management train provides drainage techniques which can be used in series to change the flow and quality characteristics of the run-off in stages.

Recent Defra guidance[1] states that drainage systems should be designed so that unless an area is designated to hold and/or convey water as part of the design, flooding does not occur:

- on any part of the site for a 1- in 30-year rainfall event
- during a 1- in 100-year rainfall event in any part of a building (including a basement) or a utility plant susceptible to water (eg pumping station or electricity substation) within the development.

2.3 Cost and performance

Guidance from the Environment Agency[2] gives an indication of the cost and performance of soakaways. The size and complexity of the soakaway largely dictates the costs involved. Overall the cost of a soakaway can be described as low/medium compared with conventional drainage. Larger soakaways cost more to construct due to higher labour costs and the use of more construction materials; disposal of excavated soil may also be an issue.

Running and maintenance costs are low, with routinely undertaken tasks as follows:

- removal of sediments and debris from pre-treatment devices (eg leaf screens, sedimentation chambers, filter strips and swales)
- cleaning of gutters or filters on downpipes
- removal of roots causing blockages
- monitoring performance.

Soakaways perform well to attenuation of peak flows. The time taken for discharge depends on the size and shape of the soakaway, as well as the surrounding soil infiltration capacity. Soakaways are capable of providing attenuation of contaminants. However, soakaways have no clear benefits with regards to biodiversity or amenity of sites[2].

The overall lifetime of a soakaway is variable and no two installations will perform in the same manner. The lifetime of the soakaway will be reduced by clogging of the water inflow and outflow (see Section 5).

3 Design

3.1 Principles

BS EN 752-4[3] states that if soakaways are to be used for site drainage, the sub-soil and the general level of the groundwater should be investigated. It is not desirable to locate a soakaway close to a building or in any other position such that the ground below foundations is likely to be adversely affected. A minimum distance of 5 m is most often quoted, but some allowance can be made for site conditions. (Note that deep-bored soakaways will require greater distance and specialist advice will be required for installing these types of soakaway.)

As a result, the design of a soakaway depends on a number of factors including the following:

- permeability of the ground
- groundwater level (preferably undertaken when water levels will be highest, during winter to spring)
- type of ground
- contamination
- space restrictions
- building foundations
- risk of ground instability and other hazards.

A soakaway consists generally of a pit from which water can percolate into the surrounding ground. Small pits may be unlined and filled with hardcore for stability, or the soakaway may take the form of seepage trenches following natural contours. Larger pits may be unfilled but lined, eg with brickwork laid dry, jointed honeycomb brickwork, perforated pre-cast concrete ring units or segments laid dry. The pit lining should be surrounded with suitable granular fill. An unfilled pit should be safely roofed and provided with access for maintenance purposes. Although square or circular pits are compact and do not take up much land area, it is often easier and cheaper to excavate trench-type soakaways if excavating equipment is available.

Perforated pre-cast concrete ring unit soakaways should be installed within a square pit, with sides about twice the selected ring unit diameter. The need to oversize the pit, for the purposes of constructing the ring unit chamber, may be used to advantage by incorporating the total excavation volume below the discharge drain invert in the design storage volume.

Granular fill can be separated from the surrounding soil by a suitable geotextile to prevent migration of fine particles into the soakaway. If migration from surrounding soil occurs, it can cause ground settlement around the soakaway sufficient to affect the stability of adjacent buildings. The top surface of the granular fill should also be covered with geotextile to prevent the ingress of fill material during and after surface reinstatement. Geotextile should not be wrapped around the outside of the ring units as it cannot be cleaned satisfactorily or removed when it has become blocked.

In order to limit any possible alteration to the quality of groundwater, attention should be paid to the source of the run-off water that is to be collected. If it is from a paved surface where there is a risk of oil or fuel spillage, a light liquid separator should be provided (in line with the Environment Agency's Pollution Prevention Guide[5]). Domestic drives and paths should not need a light liquid separator, but municipal roads and car parks will require them. A light liquid separator will also trap silt and so extend the life of a soakaway. Provision needs to be made for the interceptor to be cleaned and maintained (see Section 5).

Soakaways for draining areas less than 100 m^2 have traditionally been built as square or circular pits, either filled with rubble or lined with dry-jointed brickwork, or perforated pre-cast concrete ring units surrounded by suitable granular fill. BS EN 752-4[3] suggests that soakaways may take the form of trenches that follow natural contours. Compared with square or circular shapes, they have larger internal surface areas for infiltration of surface water for a given stored volume.

The designer should consider the merits of the more compact square or circular pits against the better rate of discharge from the trench according to soil type condition, available space, site layout and topography. For drained areas above 100 m^2, soakaways can be perforated pre-cast ring units or trench type and not substantially deeper than soakaways that serve small areas: 3 to 4 m is adequate if ground conditions allow. Although limiting the depth means that the length must be increased, trench-type soakaways are cheaper to dig with readily available excavating equipment.

There is an increasing number of soakaways that are being built using plastic cells. These are typically lightweight modular water storage cells with a high void ratio. Plastic cells can be used for either attenuation or infiltration of surface water in residential, commercial, industrial and retail applications. They can be assembled on site where multiple configurations can be formed. Proprietary components such as silt traps, flow control units and adaptors will normally be used as part of these systems.

For longevity, the soakaway should be designed with facilities for inspection and maintenance. The life of a soakaway will be reduced if its waterways become clogged by silt or floating material. With trench-type soakaways, the use of wet wells at drain outlets and T-piece inlets to the perforated or porous distributor pipes will give consistent performance. These mechanisms combine the accessibility of the pre-cast chamber with the more efficient discharge characteristics of the trench.

3.2 Site investigation and testing

Site investigation and testing should be carried out prior to design or construction work taking place; this is part of the design process. Ground conditions, even in the same location, can vary especially on previously-used brownfield land. The site investigation (including desk research and ground investigation) will be required to assess the following:

- water table depth and perched water table presence/depth (based on the worst annual case, ie during April or May)
- chemical contamination risks
- suitability of strata for soakaway discharges, including permeability.

Desk studies are preferred even for small site developments, items that should be reviewed are well records, geological maps and records, OS maps and aquifer protection maps. In the site investigation, boreholes and/or soakage trial pits can be used to determine the ground condition, soil material and presence and depth of groundwater. Soakage trial pits can also be used for the infiltration tests described in Section 3.2.3.

3.2.1 Risk assessment

The information gathered during the site investigation should be used to prepare a risk assessment, which may be required by planning and building development authorities. Issues of interest are chemical contamination, ground failure features and the effects of adjacent development.

Contamination may be a risk as a result of historical use of the ground (brownfield development). The soakaway should not connect a contamination source to a groundwater target, ie creating a source-pathway-receptor linkage. Statutory guidance on land contamination is available from www.netregs.org.uk, www.gov.wales and www.legislation.gov.uk. Prior to designing the soakaway, the potential for contamination on the site needs to be established. Where necessary, remedial measures should be undertaken.

Contamination is not the only consideration. Ground and slope instability, flooding and wash out-induced settlements should also be considered. Certain sites and parts of the UK may be at greater risk from issues such as surface settlement and instability. Local advice should be sought on these risks and how they might impact adjacent developments. Further guidance on ground instability issues and how to manage them is available in *Instability planning and management: Seeking sustainable solutions to ground movement problems*, published by ICE[4].

3.2.2 Soil infiltration

Site testing for soil infiltration rates should give representative results for the proposed site of the soakaway. This is achieved by the following:

- Excavating a soakage trial pit of sufficient size to represent a section of the soakaway.
- Filling the soakage trial pit several times in quick succession while monitoring the rate of seepage. This procedure will confirm soil moisture conditions typical of the site when the soakaway becomes operative.
- Examining site data to ensure that the area surrounding the soakaway has been assessed for variations in soil conditions, areas of filled land, preferential underground seepage routes, variations in the level of groundwater, and any geotechnical and geological factors likely to affect the long-term percolation and stability. Groundwater should not rise to the level of the base of the soakaway during annual variations in the water table.
- Local building control and/or planning authorities may be able to advise where fluctuations in groundwater level may cause a problem in the long term for any proposed depth of excavation.

Glossary

A	Area
a	Internal surface area
D	Duration
f	Soil infiltration rate
h	Hour
I	Inflow
L	Length
m	Metre
min	Minute
mm	Millimetre
O	Outflow
R	Rainfall
r	Ratio
S	Storage volume
t	Time
V	Volume
W	Width
X	Return period (years)
Z	*Z*1: Rainfall factor *Z*2: Growth factor

3.2.3 Rate test

Field investigations are required to confirm infiltration rates. The procedure recommended in this Digest is to excavate a soakage trial pit to the same depth as anticipated in the full-size soakaway. For run-off from 100 m^2 this will be 1 m to 1.5 m below the invert level of the drain discharging to the soakaway. Overall depths of excavation will be typically 1.5 m to 2.5 m for permeable areas >100 m^2 draining to the soakaway.

The soakage trial pit should be 1 m to 3 m long and 0.3 m to 1 m wide. It should have vertical sides trimmed square and, if necessary for stability, should be filled with granular material. When granular fill is used, a full-height, perforated, vertical observation tube should be positioned in the soakage trial pit so that water levels can be monitored with a dip tape. It should be possible to construct a suitably-dimensioned pit with a backhoe loader or mini-excavator.

Narrow, short pits use less water during the soakage tests but may be more difficult to trim and clean prior to testing. Measure the soakage trial pit carefully before trials. For safety reasons do not enter the soakage trial pit. A lot of water will be used to determine the soil infiltration rate so a water bowser may be needed. The inflow should be rapid so that the soakage trial pit can be filled to its maximum effective storage depth in a short time, ie to the design invert level of the drain to the soakaway. Take care that the inflow does not cause the walls of the soakage trial pit to collapse.

Fill the soakage trial pit and allow it to drain three times to near empty. Each time record the water level and time from filling, at intervals sufficiently close to clearly define water level versus time (Figure 1). The filling of the soakage trial pit should be on the same or consecutive days.

Calculate the soil infiltration rate from the time taken for the water level to fall from 75% to 25% effective storage depth in the soakage trial pit, using the lowest *f* value of the three test results for design:

$$\text{Soil infiltration rate } f = \frac{V_{p75-25}}{a_{s50} \times t_{p75-25}}$$

where:

V_{p75-25} = the effective storage volume of water in the soakage trial pit between 75% and 25% effective storage depth

a_{s50} = the internal surface area of the soakage trial pit up to 50% effective storage depth and including the base area

t_{p75-25} = the time for the water level to fall from 75% to 25% effective storage depth.

If the soakage trial pit is deeper than about 3 m, it may be difficult to supply sufficient water for a full-depth soakage test. Tests may be conducted at less than full depth but determinations of the soil infiltration rate may be lower than those from the full-depth test. This is because relationships between depth of water in the soakage trial pit, the effective area of outflow and the infiltration rate can vary with depth, even when soil conditions themselves do not vary. The variation in infiltration rate, with the depth at which the determination is made, may be as much as a factor of two.

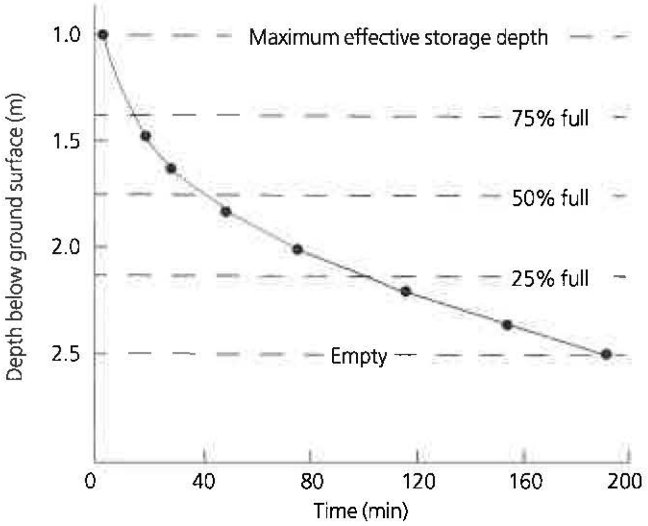

Figure 1: Field observations from a soakage trial pit 2.4 m long × 0.6 m wide × 2.51 m deep, with no granular fill

From the results of the soakage test shown in Figure 1, the calculated infiltration rate is based on a fall of water level from:

- 75% to 50% effective storage depth = 5.1×10^{-5} m/second
- 50% to 25% effective storage depth = 2.9×10^{-5} m/second.

The design method adopts the result determined from 75% to 25% effective storage depth of 3.3×10^{-5} m/second (see Box 1 on how to calculate the soil infiltration rate).

If it is impossible to carry out a full-depth soakage test, the soil infiltration rate calculation should be based on the time for the fall of the water level from 75% to 25% of the actual maximum water depth achieved in the test. The effective area of loss from the soakage trial pit is then calculated as the internal surface area of the pit to 50% maximum depth achieved, plus the base area of the soakage trial pit. In general, soakage tests should be undertaken where the drain will discharge to the soakaway.

The use of full-depth soakage tests and repeat determinations at locations along the line of trench-type soakaways is important when soil conditions vary; if the soil is fissured, infiltration rates can vary enormously. In these situations, a preliminary design length for the proposed soakaway should be calculated from the first soakage trial pit result; if the design length exceeds 10 m, a second trial should be carried out at the design length distance along the line of the soakaway. In all ground conditions, a second soakage trial pit should be dug if the trench-type soakaway (designed on the basis of one soakage trial pit) is longer than 25 m; further soakage trial pits are needed at intervals of 25 m along the line of a long soakaway. If more than one soakage trial pit is used, the mean value of the soil percolation rates determined from the soakage trial pits is adopted for the final design, but this should be above the highest annual groundwater level.

Designers should note that the results of tests may be affected by seasonal factors. In the winter and spring the soil moisture and groundwater level will be higher than in the summer. Testing under a worst case basis should be undertaken.

The soakaway should discharge from full to half-volume within 24 h in readiness for subsequent storm inflow.

3.3 Sizing

Figure 2 summarises the steps in the design calculation process.

Box 1: Calculating the soil infiltration rate

Figure 1 shows typical field observations from a soakage trial pit. It was known that the invert of the discharge drain was to be 1 m below ground surface. An effective storage depth of 1.5 m was adopted. When trimmed and cleaned, the soakage trial pit was 2.4 m long × 0.6 m wide × 2.51 m deep.

Calculations
Volume outflowing between 75% and 25% effective storage depth:

$$V_{p75-25} = 2.4 \times 0.6 \times (2.13 - 1.38) = 1.09\ m^3$$

The mean surface area through which the outflow occurs, taken to be the soakage trial pit sides to 50% effective storage depth and including the base of the pit.

$$a_{s50} = (2.4 \times 0.755 \times 2) + (0.6 \times 0.755 \times 2) + (2.4 \times 0.6) = 5.97\ m^2.$$

Using the data in Figure 1, the time for the outflow between 75% and 25% effective storage depth.

$$t_{p75-25} = 102 - 11 = 91\ \text{min}$$

Soil infiltration rate:

$$f = \frac{1.09}{5.97 \times 91 \times 60} = 3.3 \times 10^{-5}\ \text{m/second}$$

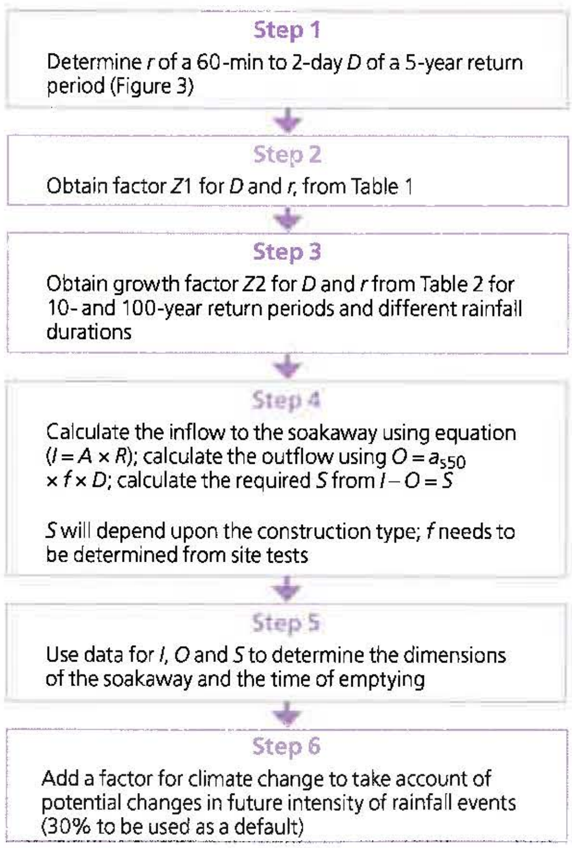

Figure 2: A summary of the design calculation process (Tables 1 and 2 are on page 8). Refer to the glossary for abbreviations

The design method for sizing a soakaway is based upon the equation of volumes:

$I - O = S$

where:

I = the inflow from the impermeable area drained to the soakaway

O = the outflow infiltrating into the soil during rainfall

S = the required storage in the soakaway to balance temporarily inflow and outflow.

3.3.1 Inflow to the soakaway

$I = A \times R$

where:

A = the impermeable area drained to the soakaway

R = the total rainfall in a design storm. Calculation of R is shown in Box 2, and can be made for 10- or 100-year design storms (note that the design value is based on the site requirements).

3.3.2 Outflow from the soakaway

$O = a_{s50} \times f \times D$

where:

a_{s50} = the internal surface area of the soakaway to 50% effective storage depth: this excludes the base area which is assumed to clog with fine particles and become ineffective in the long term

f = the soil infiltration rate determined in a soakage trial pit at the site of the soakaway

D = the storm duration.

Box 2: Calculating design rainfall

Values of design rainfall, R, can be determined using Figure 3 and Tables 1 and 2 for different storm durations with a 10- and 100-year return period. The notation MX-D min is used to identify the storm, where
X = the return period (years)
D = the storm duration (min).

The 10-year return period rainfall of 15 min duration (M10-15 min), or of 30 min duration (M10-30 min), is calculated and illustrated in the rainfall design example that follows.

Rainfall design example

From the map shown in Figure 3, determine the rainfall ratio, r, for the location of the soakaway (interpolating between contours). Use the determined rainfall ratio in Table 1 to give the factor $Z1$ for the calculation of the 5-year return period rainfall total, M5-D min, for different storm durations, D.

The basis of the calculation is the 5-year return period rainfall of 5 min duration (M5-60 min). This can be taken to be 20 mm for all parts of the UK.

M5-D min rainfall
= M5-60 min rainfall × $Z1$
= 20 mm × $Z1$

M10-D min
= M5-D min × $Z2$
where factor $Z2$ is found from Table 2.

For example, if, for the soakaway location, r, shown on Figure 3 = 0.42, the M5-15 min can be found as follows:

M5-15 min rainfall = 20 mm × $Z1$ (for 15 min duration).

To calculate factor $Z1$, select the required rainfall duration, D, (eg 15 min), from Table 1 and interpolate the appropriate rainfall ratio, r, at the chosen site.

For example:
D = 15 min
r = 0.42
$Z1$ = 0.64
= 20 mm × 0.64

M5-15 mm rainfall = 12.8 mm

M5-30 min rainfall = M5-60 min rainfall × $Z1$ (for 30 min duration)
= 20 mm × 0.81
= 16.2 mm

Adjustment for 10-year return period example

The required 10-year return period rainfalls used in the soakaway design are calculated by interpolating the growth factors $Z2$ from Table 2.

For example (England and Wales):

M10-15 min rainfall
= M5-15 min rainfall × $Z2$
= 12.8 mm × 1.23
= 15.7 mm.

M10-30 min rainfall
= 16.2 mm × 1.24
= 20.1 mm.

Adjustment for 100-year return period example

The required 100-year return period rainfalls used in the soakaway design are calculated by interpolating the growth factors $Z2$ from Table 2.

For example (England and Wales):

M100-15 min rainfall
= M5-15 min rainfall × $Z2$
= 12.8 mm × 1.95
= 24.96 mm.

M100-30 min rainfall
= 16.2 mm × 2.00
= 32.4 mm.

Other durations are calculated in the same way. This procedure to determine the 10-year or 100-year rainfalls must be used because the basic data are available only for 5-year return periods.

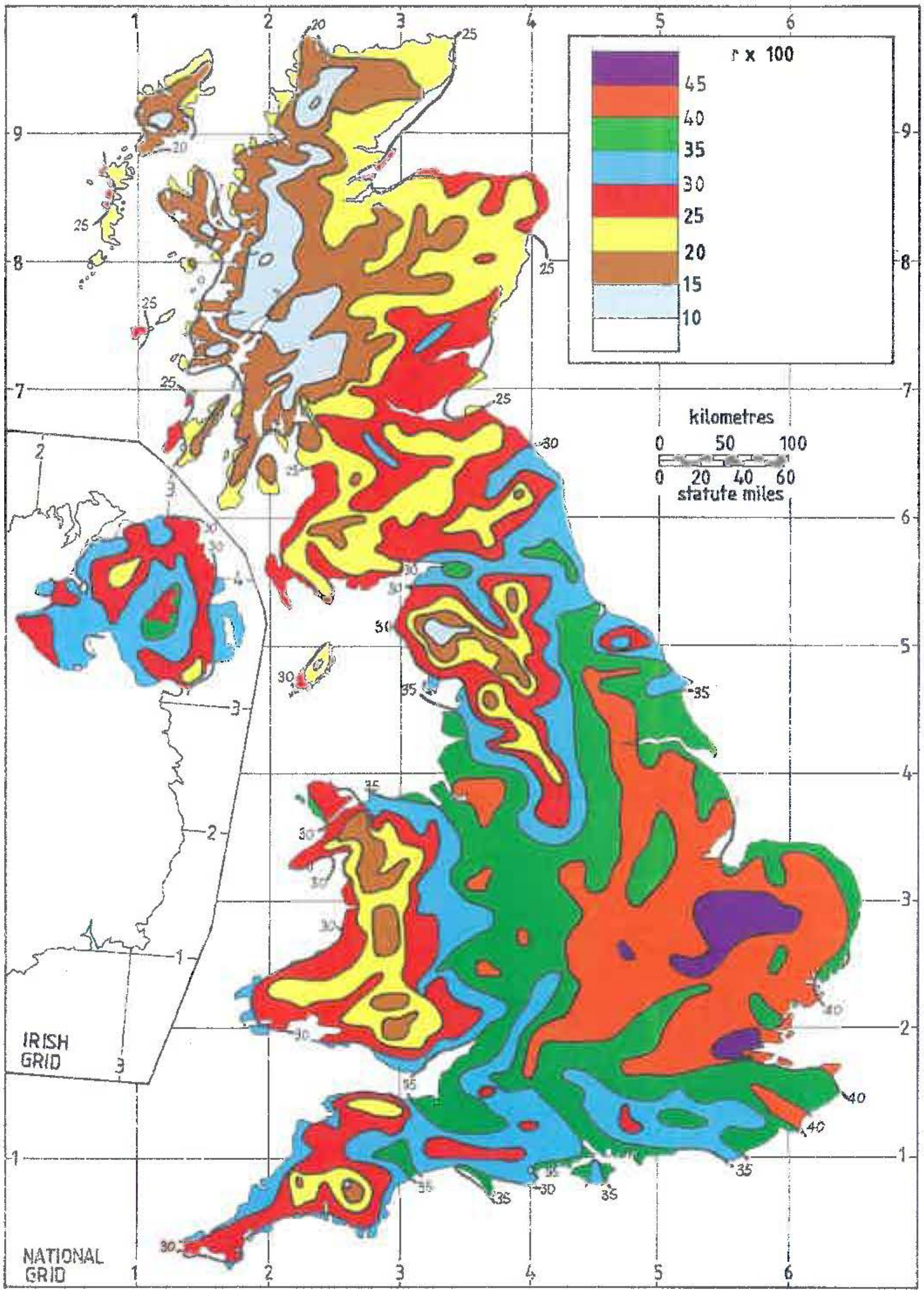

Figure 3: Ratio of 60-min to 2-day rainfall duration of a 5-year return period[1] (image © Department for Environment, Food & Rural Affairs)

3.3.3 Required storage volume in the soakaway, *S*

Storage must be equal to, or greater than, inflow minus outflow, defined above in sections 3.3.1 and 3.3.2, and is the required effective volume available between the base of the soakaway and the invert of the drain discharging to the soakaway. There are four steps in the design procedure:

1. Carry out a site investigation to determine the soil infiltration rate (see section 3.2).
2. Decide on a construction type (eg filled pit in square, circular or trench form, or perforated concrete ring units with granular surround).
3. Calculate the required storage volume, *S*, from inflow minus outflow for a range of durations of 10- or 100-year design storms to determine the maximum storage predicted for the type of soakaway.
4. Review the design to ensure its overall suitability considering space requirements, site layout and time for emptying.

Table 1: Values of factor *Z1* for rainfall duration (*D*) and ratio (*r*)

	Rainfall duration (*D*)									
	Minutes (min)				Hours (h)					
Ratio (*r*)	5	10	15	30	1	2	4	6	10	24
0.12	0.22	0.34	0.45	0.67	1.00	1.48	2.17	2.75	3.70	6.00
0.15	0.25	0.38	0.48	0.69	1.00	1.42	2.02	2.46	3.23	4.90
0.18	0.27	0.41	0.51	0.71	1.00	1.36	1.86	2.25	2.86	4.30
0.21	0.29	0.43	0.54	0.73	1.00	1.33	1.77	2.12	2.62	3.60
0.24	0.31	0.46	0.56	0.75	1.00	1.30	1.71	2.00	2.40	3.35
0.27	0.33	0.48	0.58	0.76	1.00	1.27	1.64	1.88	2.24	3.10
0.30	0.34	0.49	0.59	0.77	1.00	1.25	1.57	1.78	2.12	2.84
0.33	0.35	0.50	0.61	0.78	1.00	1.23	1.53	1.73	2.04	2.60
0.36	0.36	0.51	0.62	0.79	1.00	1.22	1.48	1.67	1.90	2.42
0.39	0.37	0.52	0.63	0.80	1.00	1.21	1.46	1.62	1.82	2.28
0.42	0.38	0.53	0.64	0.81	1.00	1.20	1.42	1.57	1.74	2.16
0.45	0.39	0.54	0.65	0.82	1.00	1.19	1.38	1.51	1.68	2.03

Table 2: Growth factor *Z2* for M10 and M100 rainfall duration derived from M5 rainfall duration

	M10 growth factor *Z2*		M100 growth factor *Z2*	
M5 rainfall (mm)	England and Wales	Scotland and Northern Ireland	England and Wales	Scotland and Northern Ireland
5	1.20	1.18	1.84	1.91
10	1.22	1.19	1.91	1.97
15	1.23	1.19	1.95	1.97
20	1.24	1.20	2.00	1.97
25	1.24	1.19	2.03	1.93
30	1.24	1.18	2.01	1.89
40	1.22	1.18	1.97	1.85
50	1.21	1.18	1.94	1.82
75	1.19	1.17	1.90	1.78
100	1.17	1.16	1.81	1.72

This design method for sizing soakaways contains assumptions which generally combine to increase the factor of safety against surface flooding of the design:

- The percentage run-off is taken as 100% from the drained area, ie no reduction is made to the design run-off volume discharged to the soakaway for losses due to surface wetting or the filling of puddles during the storm.
- No allowance is made for the time taken for run-off to discharge to the soakaway. The required storage volume is calculated on the basis of instantaneous discharge to the soakaway. The outflow from the soakaway is under-estimated: higher infiltration rates occur at greater depths of storage in practice than are adopted in design, and because the outflow is calculated on the basis of the rainfall duration rather than the run-off duration. The latter may be considerably longer, depending on the length of the drains.

3.4 Climate change

Designers should consider the impact of climate change in soakaway design assessments. This will reduce the likelihood of problems associated with under-sizing of soakaways.

The UK Climate Projections (UKCP09: http://ukclimateprojections.metoffice.gov.uk) provides climate information designed to help planning for adaptation to climate change throughout the 21st Century. Projections of climate change allow for uncertainty due to the natural variability and, the incomplete understanding of the climate system and its imperfect representation in models. These uncertainties are accounted for by giving the probabilities of a range of possible outcomes.

Figure 4 shows changes, from 1961 to 2006, in the contribution from heavy precipitation in the winter (the blue bar labelled 'W' on Figure 4) and summer (the yellow bar labelled 'S' on Figure 4) precipitation in the nine Met Office climatological regions of the UK.

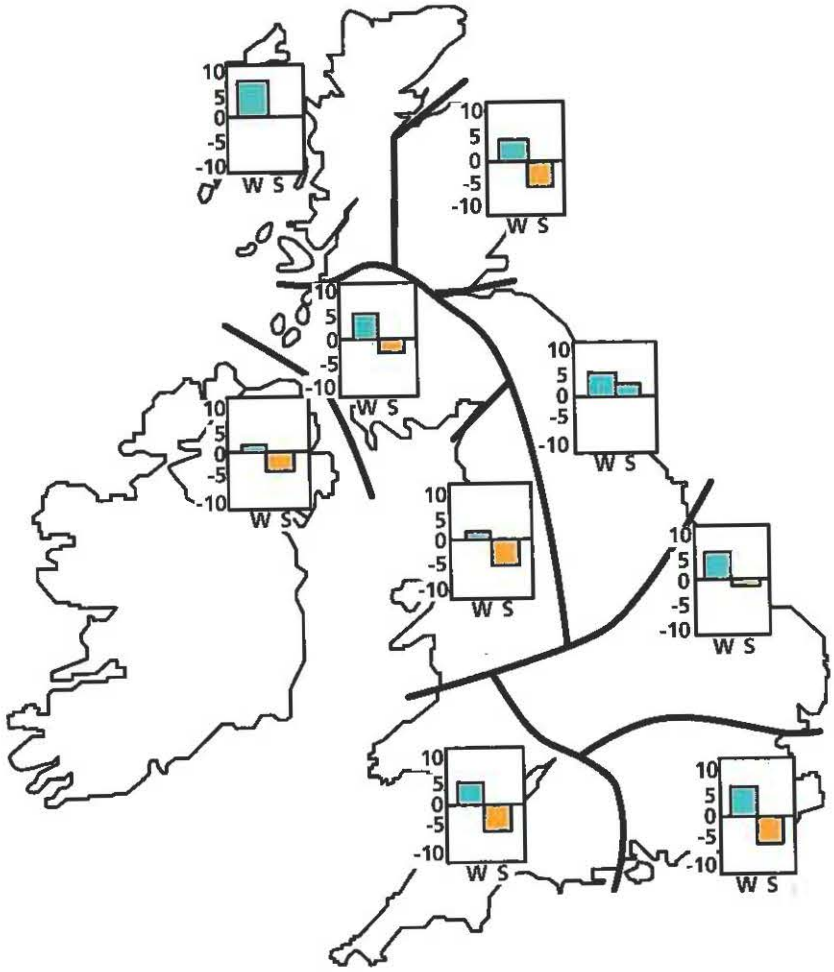

Figure 4: Trends over the period 1961 to 2006 in the contribution (%) made by heavy precipitation events to total precipitation[6]. Positive trends are labelled 'W' for winter and shown in blue, negative trends are labelled 'S' for summer and shown in yellow. Image © UK Climate Impacts Programme

All regions have experienced an increase in the contribution to winter rainfall from heavy precipitation events. In summer, all regions show decreases except northern Scotland which experienced no change and north east England which shows an increase.

The design should assume a different value of rainfall inflow (*I*) into the soakaway and ignore any other changes such as impact on outflow. Unless the soakaway is intended to have only a short working life (10 years or less) then a climate change factor for *I* should be adopted as I_{cc}.

A value of 30% increase should be assumed, unless the designer can demonstrate that a lower, or indeed higher, value would satisfactorily deal with the risk of climate change.

The designer should recalculate the value of '*R*' to add 30% (R_{cc}) and then use this to calculate I_{cc}.

It should be noted that the inclusion of a climate change factor within soakaway design is not a requirement of building regulations. Therefore, designers and contractors who allow for climate change are doing so as a matter of best practice rather than meeting regulatory requirements. Further information and advice on climate change, and how to use this information in design, can be obtained from the Met Office (www.metoffice.gov.uk) or organisations such as UKCIP (www.ukcip.org.uk).

4 Construction

Installing a soakaway provides a means by which rainwater from a building can be collected and dispersed into the soil in a suitable location. The area of the ground to be excavated should be lower than the building if possible, but certainly not higher.

The ground can be excavated by hand, but a mini-digger will complete the work faster, and if used by a trained operative it will be safer. The total depth may need to reach 3 m to 4 m. Trench-type soakaways do not need to be as deep, but will require a suitable free length to take the excavation without disturbing services or adjacent structures.

Once the excavation has been completed, a level 100 mm layer of gravel blinding should be laid over the base. If the soakaway is to be filled with granular material or plastic cells then a geotextile can be used to line the excavation. The fabric should be laid over the pit so that it sits centrally (Figure 5). Ease the middle of the fabric down to the bottom of the pit so that it lies as flat as possible. Drainage and inspection pipes should be positioned and then the granular fill or plastic cells can be added. The drainage pipes should be laid to the soakaway from the surface water collection manhole and the water will gradually seep away into the surrounding soil. However, this arrangement can eventually silt up the soakaway.

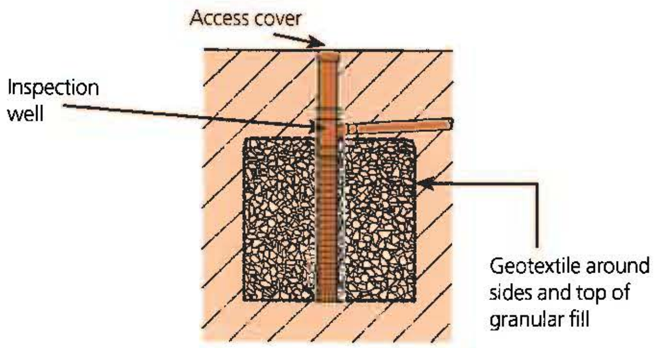

Figure 5: Cross-section of a small, filled-type soakaway with a perforated inspection well extending to the base of the soakaway, providing access to the discharge drain outlet

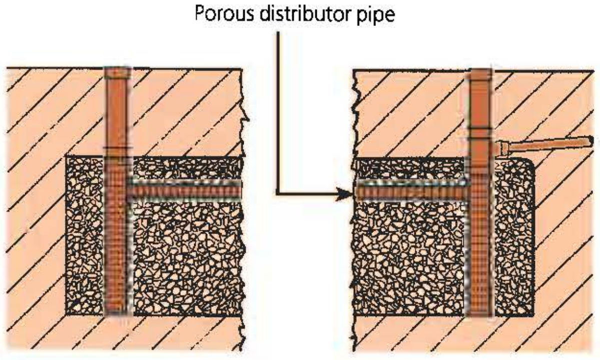

Figure 6: Cross-section of a trench-type soakaway with a horizontal distributor pipe

Alternatively perforated pre-cast concrete ring units, squares or dry jointed brickwork can be used in order to form the soakaway. These types should have a foundation of a concrete base to prevent collapse of the ground.

The soakaway should be connected by a pipe to the area that is being drained, which could be a roof or an area of ground such as a car park. A trench should be excavated from the building or other area to be drained for the drain pipe to run in. The depth of this will be dependent on the ground levels, but adequate fall along its entire length is needed to ensure proper drainage.

As in all construction, installing a soakaway will require a health and safety risk assessment to be undertaken. The risk assessment should identify the hazards and put into place the measures to manage risk.

5 Maintenance, inspection and monitoring

All soakaways should be provided with some form of inspection access, so that the point of discharge of the drain to the soakaway can be seen. This access will identify the location and allow material to be cleared from the soakaway. Lined soakaways have the advantage of access for inspection and cleaning, and this should be a feature of soakaways. The location should also be clearly identified on any development plans, therefore allowing a point of reference for future property owners or those involved in maintenance (note that these points are not planning or building regulation requirements, but are good practice).

Monitoring of soakaway performance can be informative about changes in the soil infiltration rate and in warning of soakaway blockage in the long term. The inspection access should provide a clear view to the base of the soakaway, even for filled-type soakaways (Figure 5). For small, filled soakaways, a 225 mm perforated pipe provides a suitable inspection well.

Trench-type soakaways should have at least two inspection access points, one at each end of a straight trench, with a horizontal perforated or porous distributor pipe linking the ends along the top of the granular fill (Figure 6). It may be convenient with a trench-type soakaway to have several drain discharge points along the length of the trench, each connected to the soakaway via an inspection access chamber.

In trench-type soakaways, the movement of suspended and floating material into the distributor pipe can be minimised by using wet wells with a T-piece inlet fitted to the distributor pipe (Figure 7). The installation of two or more T-piece inlets to distributor pipes, in two or more trench-type soakaways, may be appropriate for large wet well designs. The advantages of sedimentation of fine material in the pre-cast chamber (for ease of maintenance and extended operating life) are combined with the more efficient trench discharge characteristics.

Access points enable the point of discharge of the drain to be viewed. For small filled soakaways, a 225 mm perforated pipe can be used as an inspection well. Trench-type soakaways require at least two inspection access points, one at each end of a straight trench. These should be linked, near the top of the granular fill, by a horizontal perforated or porous distributor pipe. Where more than one drain feeds a trench-type soakaway, each connection should be via a suitable access chamber.

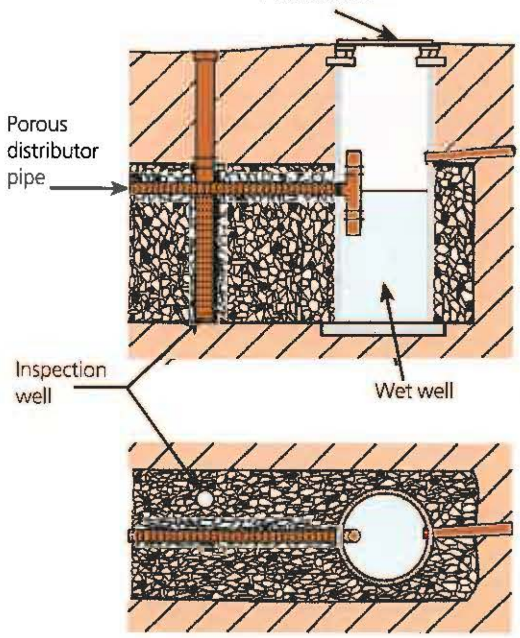

Figure 7: Cross-section of a trench-type soakaway with a large wet well, equipped with a T-piece overflow to the porous distributor pipe and separate inspection well

6 Design examples

EXAMPLE A

Design a soakaway to receive surface water from a 95 m² impermeable surface for a site at Southampton

Find the rainfall ratio from Figure 3 ($r = 0.35$) and calculate the storm rainfalls for a range of storm durations. Use Tables 1 and 2 to calculate the storm duration. Results are given in Table 3 for 10- and 100-year return periods.

Assuming the results from a soakage test (Figure 1) were obtained at the site, they can be used to design a soakaway which will be filled with granular material having 30% free volume. The percentage void space of any granular fill must be pre-determined for use in the design method.

Take the soakaway dimensions as:

2.4 m long × 2.5 m deep × 1.5 m effective storage depth, so that the pit can form part of the full-scale soakaway.

Calculate the design width of the soakaway:

Volume equation $I - O = S$.

A.1 Inflow to soakaway (I)

$I = A \times R$

= impermeable surface area × M10-D min rainfall eg for 10 min storm duration, M10-10 min = 12.4 mm = 0.0124 m

$I = 95 \times 0.0124$

$= 1.178\ m^3$.

A.2 Outflow from soakaway (O)

$O = a_{s50} \times f \times D$ = internal surface area of pit to 50% storage depth (excluding base area) × soil percolation rate × storm duration.

For a rectangular pit 2.4 m long × 1.5 m effective storage depth × W m wide:

$a_{s50} = 2 \times (2.4 + W) \times (1.5 \div 2) = 3.6 + 1.5\,W\ m^2$

$f = 3.3 \times 10^{-5}$ m/second from soakage test

$O = (3.6 + 1.5\,W) \times (3.3 \times 10^{-5}) \times (D \times 60)\ m^3$.

A.3 Soakaway storage volume (S)

S = effective volume of soakaway with 30% free volume = $2.4 \times 1.5 \times W \times 0.3 = 1.08\,W\ m^3$.

For satisfactory storage of the M10-10 min run-off:

$I - O = S$

$1.178 - (3.6 + 1.5\,W) \times (3.3 \times 10^{-5}) \times (10 \times 60) = 1.08\,W$.

Required soakaway width:

$W = 1$ m.

Repeat the calculation for a range of M10-D min storms and determine the maximum width. Results are summarised in Table 4.

Table 4: Rainfall results for a range of M10-*D* min storms

Storm duration D (min)	Required soakaway width W (m)
10	1.00
15	1.20
30	1.41
60	1.53
120	1.41
240	0.99

A soakaway 2.4 m long × 1.5 m effective storage depth × 1.53 m wide would be suitable with the critical storm duration around 1 h for 10-year events. The design may be suitable for the site layout but, if not, alternative shapes could be investigated. For example, if a narrow soakaway was necessary similar to the soakage trial pit (0.6 m wide × 1.5 m effective storage depth), calculations show that it must be 5.1 m long, with the critical storm duration around 30 min.

Check on time of emptying half storage volume, t_{s50}

$t_{s50} = S \times 0.5 / a_{s50} \times f = (1.08 \times 1.53) \times 0.5/(3.6 + [1.5 \times 1.53]) \times (3.3 \times 10^{-5})$ seconds

$t_{s50} = 1.2$ h.

This design is clearly satisfactory but with soil infiltration rates of about 10^{-7} it may take days for the soakaway to half empty so the performance would be unsuitable.

Table 3: Rainfall results for a range of storm durations (10- and 100-year return periods)

Storm duration D (min)	M5-D min = 20 mm x Z1	Z2 (10-year return period)	M10-D min = R (mm)	Z2 (100-year return period)	M100-D = R (mm)
10	10.2	1.22	12.4	1.91	19.4
15	12.4	1.23	15.2	1.95	24.0
30	15.8	1.24	19.6	2.00	31.4
60	20.0	1.24	24.8	2.03	40.6
120	24.4	1.24	30.3	2.01	49.0
240	30.0	1.22	36.6	1.97	59.0
360	33.8	1.21	40.9	1.94	65.6
600	39.0	1.19	46.5	1.90	74.0

EXAMPLE B

Design an alternative soakaway for a site at Southampton, using perforated concrete ring units

Use the rainfall results given in Table 3. The soil infiltration rate is 3.3×10^{-5} m/second and the effective storage depth is 1.5 m. Use an initial design of 900 mm internal diameter concrete ring units, placed in a square pit of side length L, with granular backfill with 30% free volume between the rings and the sides of the pit.

Volume equation $I - O = S$.

B.1 Inflow to soakaway (I)

$I = A \times R$

$= 95 \times 0.0124$

$= 1.178\ m^3$ for M10-10 min storm.

B.2 Outflow from soakaway (O)

$O = a_{s50} \times f \times D$

For a square soakaway with 1.5 m effective storage depth and excluding base area:

$a_{s50} = 4 \times L \times 1.5 \times 0.5$

$= 3\ L\ m^2$

$O = 3\ L \times (3.3 \times 10^{-5}) \times (D \times 60)\ m^3$

$= 0.0594\ L\ m^3$ for M10-10 min storm.

B.3 Soakaway storage volume (S)

= free volume in granular fill + volume within concrete ring units.

Volume within 900 mm ring units = $3.142 \times 0.45^2 \times 1.50 = 0.95\ m^3$. Free volume in granular fill surrounding ring units in a square pit:

$= (1.5\ L^2 - [3.142 \times 0.5^2 \times 1.5]) \times 0.3$

$= 0.45\ L^2 - 0.353\ m^3$.

(0.5 m = internal radius of the concrete ring plus 50 mm wall thickness).

Total volume $S = 0.95 + (0.45\ L^2 + 0.353) = 0.597 + 0.45\ L^2\ m^3$.

For satisfactory storage of the M10-10 min run-off:

$I - O = S$

$1.178 - 0.0594\ L = 0.597 + 0.45\ L^2$

$0.45\ L^2 + 0.0594\ L - 0.581 = 0$.

Solving the quadratic equation:

Side length $L = -0.0594 + (0.0594^2 + 4 \times 0.45 \times 0.581)^{0.5} / 2 \times 0.45$

$L = 1.07$ m.

Repeat for a range of M10-D min storms and determine the maximum size of excavation. Results are summarised in Table 5.

Table 5: Maximum size of excavation

Storm duration D (min)	Required soakaway pit L (m)
10	1.07
15	1.28
30	1.49
60	1.62
120	1.59
240	1.40

Choose a soakaway 1.62 m^2 subject to a check on time of emptying half the storage, t_{s50}:

$t_{s50} = S \times 0.5 / a_{s50} \times f = (0.597 + 0.45\ (1.62)^2) \times 0.5 / (3 \times 1.62) \times (3.3 \times 10^{-5})$ seconds = 1.5 h

If the initial design using 900 mm concrete units and the calculation of the pit side length is unsatisfactory, select another standard size of unit and repeat the calculation.

In order to account for the risk presented by climate change the designer can add to the soakaway volume (30% is suggested). There is no statutory requirement to take account of climate change, but it may be advisable if a long life is expected from the development and the soakaway.

EXAMPLE C

Design a trench-type soakaway to receive surface water run-off from a 400 m² impermeable surface

Choose a trench 0.6 m wide, 1.5 m effective storage depth, with granular fill having 30% free volume. Calculate the soakaway trench length, L. The rainfall ratio r is 0.35 and soil infiltration rate f is 3.3×10^{-5} m/second.

Volume equation $I - O = S$.

C.1 Inflow to soakaway (I)

$I = A \times R$

$= 400 \times 0.0124$

$= 4.96\ m^3$ for M10-10 min storm.

C.2 Outflow from soakaway (O)

$O = a_{s50} \times f \times D$

$a_{s50} = 2 \times (0.6 + L) \times (1.5 \div 2)$

$O = (0.9 + 1.5\,L) \times (3.3 \times 10^{-5}) \times (D \times 60)\ m^3$

$= 0.01782 + 0.0297\,L\ m^3$ for M10-10 min storm.

C.3 Soakaway storage volume (S)

Soakaway storage volume, S, = effective volume in trench with 30% free volume:

$S = L \times 0.6 \times 1.5 \times 0.3 = 0.27\,L\ m^3$.

For satisfactory storage of the M10-10 min run-off:

$I - O = S$

$4.96 - 0.01782 - 0.0297\,L = 0.27\,L$

$L = 16.5$ m.

Repeat the calculation for a range of M10-D min storms and determine the maximum length. The results are summarised in Table 6. A soakaway 22 m long, 1.5 m effective storage depth and 0.6 m wide is suitable; time for half emptying is 45 min. Such a design might be compatible with site layout and topography but an alternative trench cross-section could be investigated. Maintain the 1.5 m effective storage depth but use trench widths of 0.3 m and 1 m. The design lengths of the trench for the widths are shown in Figure 8 for a range of 10-year return period storms. As the design width increases, the required length decreases and the critical storm duration increases. So if a design fails to meet the 24-h time for half empty criterion, reducing the width and thereby increasing the length of a trench-type soakaway might achieve a satisfactory design. Similarly, if a design based upon a perforated pre-cast concrete ring unit soakaway fails the 24-h criterion, a trench-type soakaway may be satisfactory.

With narrower, longer soakaways the volume of the soakaway trench is reduced relative to the wider trench designs – the storage is reduced because of the enhanced outflow performance. The volume of the trench designed 0.3 m wide is only 70% of a 1 m wide trench so there are savings in the cost of excavation and granular fill material (Figure 8).

In order to account for the risk presented by climate change the designer can add to the soakaway volume (30% is suggested). There is no statutory requirement to take account of climate change, but it may be advisable if a long life is expected from the development and the soakaway.

Table 6: Rainfall results for a range of M

Storm duration D (min)	Required soakaway length L (m)
10	16.5
15	19.7
30	21.9
60	21.9
120	19.2
240	14.0

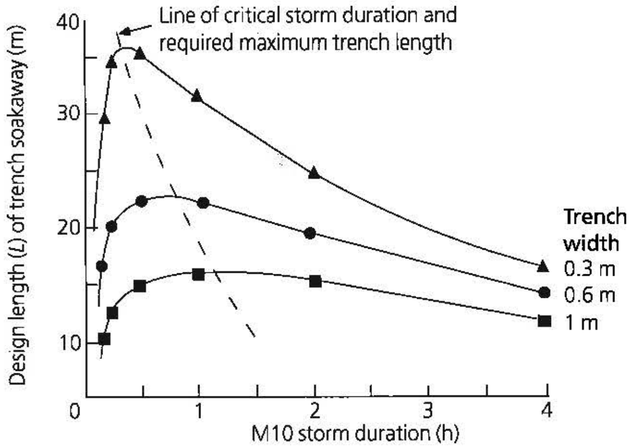

Figure 8: Required design length of a trench soakaway plotted against design storm duration for 10-year return period storms

7 References

1. Department for Environment, Food and Rural Affairs (Defra). Sustainable Drainage Systems: Non-statutory technical standards for sustainable drainage systems. London, Defra, 2015.

2. Environment Agency, Rural Sustainable Drainage Systems (RSuDS). Bristol, Environment Agency, 2012. Design and analysis of urban storm drainage. The Wallingford Procedure. National Water Council Standing Technical Committee Reports No 31. London, Defra, 1981.

3. BSI. BS EN 752-4:2005. Drain and sewer systems outside buildings – Part 4: Hydraulic design and environmental considerations. London, BSI, 2005.

4. ICE. Instability planning and management: seeking sustainable solutions to ground movement problems (Eds McInnes R G, Jakeways J). London, ICE, 2002.

5. Environment Agency. Polution Prevention Guide: Use and design of oil separators in surface water drainage systems. PPG3. London, Environment Agency, 2006.

6. Jenkins G J, Perry M C and Prior M J. The climate of the UK and recent trends. Oxford, UK Climate Impacts Programme, 2008.

8 Further reading

BSI. BS 8301:1985. Code of practice for building drainage. London, BSI, 1985.

Quinn P, Jonczyk J, Rimmer D and Hewett C. Store slow filter: The proactive approach to Farm Integration Runoff Management (FIRM) plans with respect to nutrients. Newcastle University, Newcastle, 2007.

Acknowledgements

The research and writing for Digest has been funded by BRE Trust