VOLUME 4 GEOTECHNICS AND DRAINAGE
SECTION 2 DRAINAGE

PART 3

HD 33/16

DESIGN OF HIGHWAY DRAINAGE SYSTEMS

SUMMARY

This document gives guidance and requirements on the selection of the types of surface and sub-surface drainage for the UK motorway and all-purpose trunk road network. It describes the various alternative solutions that are available to drain the UK motorway and all-purpose trunk road network, including their potential to control pollution and flooding. It also includes guidance and requirements on drainage of earthworks associated with highway schemes and appropriate signing for pollution control devices.

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HIGHWAYS ENGLAND

HD 33/16
Volume 4, Section 2,
Part 3

TRANSPORT SCOTLAND

WELSH GOVERNMENT
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DEPARTMENT FOR INFRASTRUCTURE

Design of Highway Drainage Systems

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Volume 4 home page

Volume 4 home page

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Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

Volume 4 home page

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Contents

Chapter

Volume 4 home page

Volume 4 home page

1. INTRODUCTION

Background

1.1 This Standard gives requirements on the selection of the types of surface and sub-surface drainage for the UK motorway and all-purpose road network. It describes the various alternative solutions that are available to drain the UK motorway and all-purpose road network, including their potential to control pollution and flooding. It also includes guidance and requirements on drainage of earthworks associated with highway schemes and appropriate signing for pollution control devices

1.2 The term "Roads" used in Scotland and Northern Ireland is synonymous with the term "Highways" defined in the Highways Act 1980. In this document the term highway will be used as the standard terminology, however for clarity, where the term "roads" is used in this document, it should be taken to be equivalent to "highway".

Scope

1.3 The information given on drainage design is applicable to all UK motorway and all-purpose road network projects. (In Northern Ireland the guidance will be applicable to those roads designated by the Overseeing Organisation). It provides a summary of design documents available, primarily those published on behalf of the Overseeing Organisations. It describes the various alternative solutions that are available to drain the UK motorway and all-purpose road network, including their potential to control pollution and flooding. It advises upon selection in principle, and gives advice and requirements on the detailed design of the various pavement edge drainage alternatives with regard to available design guides.

Implementation

1.4 This Standard should be used forthwith for all schemes currently being prepared provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay progress. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation.

Mutual recognition clause

1.5 Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with:

a) a standard or code of practice of a national standards body or equivalent body of any EEA state or Turkey;

b) any international standard recognised for use as a standard or code of practice by any EEA state or Turkey;

c) a technical specification recognised for use as a standard by a public authority of any EEA state or Turkey; or

d) a European Technical Assessment issued in accordance with the procedure set out in regulation (EU) No305/2011;

provided that the relevant standard imposes an equivalent level of performance and safety provided for by the stated Standard or technical specification.

"EEA State" means a state which is a contracting party to the European Economic Area Agreement.

"British Standard" means any standard published by the British Standards Institution including adopted European or other international standards.

Design Principles

1.6 There are three major objectives in the drainage of the UK motorway and all-purpose road network:

i) removal of surface water from the carriageway as quickly as possible to provide safety and minimum nuisance to the travelling public;

ii) provision of effective sub-surface drainage to maximise longevity of the pavement and its associated earthworks; and

iii) minimisation of the impact of the runoff on the receiving environment in terms of flood risk and water quality.

It is also necessary to provide for drainage of earthworks and structures associated with the highway.

1.7 The performance of pavement foundations, earthworks and structures can be adversely affected by the presence of water, and good drainage is therefore an important factor in ensuring that the required level of service and value for money are obtained. Highway drainage can be broadly classified into two elements: surface and sub-surface drainage, but these two aspects are not completely disparate. Surface water is able to infiltrate into road foundations, earthworks or structures through any surface which is not completely impermeable, and will thence require removal by sub-surface drainage unless other conditions render this unnecessary.

1.8 The necessary objectives can be achieved by:

i) combined systems, where both surface water and sub-surface water are collected in the same pipe; or

ii) separate systems, where the sub-surface water is collected in a separate drainage conduit from the one which is used for collection of surface water. Sub-surface water of a separate system will be collected in a fin or narrow filter drain.

Each system has certain advantages and disadvantages and one may be more appropriate than the other in any particular situation.

1.9 Drainage networks incorporating systems such as oil separators, sediment traps, filter drains, wetlands and other vegetated systems can, by virtue of their design, provide a degree of control over pollution and flood control. The three main processes applicable to the treatment of highway runoff are:

- sedimentation – the removal of suspended solids;
- separation – the removal of all solids and non-aqueous liquids;
- vegetated treatment processes, including filtration, settlement, adsorption, biodegradation and plant uptake, depending on the type and combination of systems.

The selection and design of systems will depend on the pollution load, the risk of spillage or flood and the site conditions, particularly if protected species or sites may be affected. In practice, the network is likely to be a combination of systems.

Definitions

1.10 The definitions of the various drainage asset types are contained in HD 43 (DMRB 4.2) whereas environmental definitions are contained in HD 45 (DMRB 11).

Fluvial (see 2.2 below) is defined as relating to, being of, or inhabiting a river or stream.

2. DRAINAGE SELECTION PROCESS

2.1 The drainage selection process is illustrated in Figure 2.1, and must include water quality and flood risk issues as well as providing sufficient drainage to the highway itself. The purpose of HD 33 is to guide the designer with selecting the most appropriate drainage solutions. In order to select the most appropriate solution, he or she must take into account several factors before deciding on which system to utilise. These decisions are recorded in the project data on how they have taken it into account.

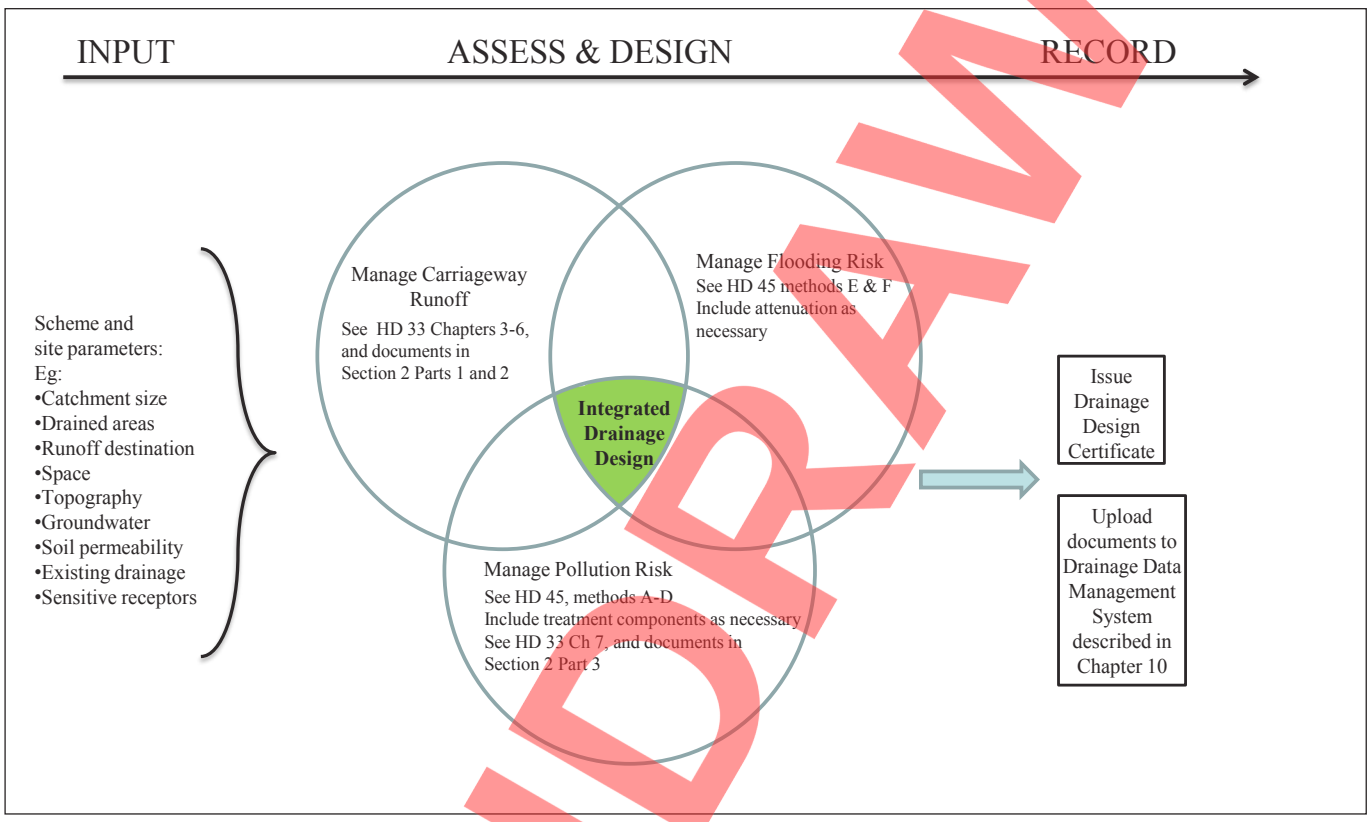

Figure 2.1: High Level Drainage Design Process

Destinations for highway runoff

2.2 The following discharge destinations are the order of preference for highway runoff options:

1. Ground;
2. Surface water course;
3. Surface water sewer.

Highway runoff must not outfall directly into natural ponds, lakes, canals, reservoirs or a groundwater Source Protection Zone 1 (Inner Zone)

2.3 Highway runoff must outfall into the ground except where one or more of the following criteria can be demonstrated:

- The rate of surface runoff is greater than the rate at which water can infiltrate into the ground. In this case as much of the water as reasonably practicable must be discharged by infiltration to ground;

- There is an unacceptable risk of ground instability or subsidence;
- There is an unacceptable risk of pollution from mobilising existing contaminants on the site;
- Infiltration is not compliant with the water quality requirements;
- There is an unacceptable risk of groundwater flooding.

2.4 Highway runoff that cannot discharge into ground must always outfall to a fluvial surface water body except where any of the following can be demonstrated:

- It is not reasonably practicable to convey the runoff to a surface water body;
- Pumping of the surface water runoff, either on site or further downstream, would be required and there is a reasonably practicable alternative;
- Discharge would result in an unacceptable risk of flooding from the surface water body. (The use of "reasonably practical" in this document is judged between the Overseeing Organisation and the designer. Where one party deems it not to be "reasonably practical", a conversation would happen between the Overseeing Organisation and the designer to discuss. The proposal may or may not be accepted by the Overseeing Organisation).

2.5 Highway runoff that cannot outfall into the ground or to a fluvial surface water body must outfall to a surface water sewer or local highway drain, except where it can be demonstrated that it is not reasonably practicable to do so.

2.6 Surface runoff that cannot outfall into the ground, a fluvial surface water body or a surface water sewer or local highway drain must outfall to a public combined sewer, not a foul sewer.

2.7 Where highway runoff outfalls to a fluvial surface water body, the following design return periods apply:

1 in 1 year – No surcharge of the drainage system (refer to paragraph 7.2)

1 in 5 years – No flooding from the drainage system (refer to paragraph 7.2)

1 in 100 years – Flood risk assessment for receiving surface water body (refer to HD 45)

2.8 In demonstrating that runoff cannot outfall to the preferred destinations in paragraph 2.2, designers should explain why outfalling to those destinations has not been proposed, either in whole or in part, for the highway runoff. The explanation must be included in a report to be submitted to the Overseeing Organisation with the documents appended to the drainage certificate described in HD 50 (DMRB 4.2.1).

Pollution Control Systems

2.9 Water quality treatment and control components must be designed to ensure that they function effectively and meet the requirements of HD 45.

2.10 Where the sensitivity of the potential hazards and sensitivity of the receiving water body requires a level of treatment which is more stringent than the requirements of HD 45, then advice from the Overseeing Organisation should be obtained. The design of the system should make use of an environment that incorporates and supports vegetation where reasonably practicable, for further guidance refer to HA 103.

Relevant DMRB documents

2.11 Guidance and requirements on the design, construction, operation and maintenance of drainage for the UK motorway and all-purpose road network can be found in the following documents.

2.12 Chapter 8 of this document gives examples of drainage systems that have the potential to mitigate the polluting and flood risk effects of runoff.

2.13 Guidance and requirements on the assessment of the risk of either pollution or flooding is given in HD 45 Road Drainage and the Water Environment (DMRB 11.3.10).

2.14 HA 103 Vegetated Drainage Systems gives guidance on ponds, swales, basins and other vegetated systems.

2.15 HA 118 Design of Soakaways (DMRB 4.2) gives design guidance and requirements on how soakaways may be incorporated into systems used to treat and store highway runoff prior to discharging to ground. It describes the steps needed to protect receiving groundwater and the constraints these may place on soakaway design and construction.

2.16 HA 119 Grassed Surface Water Channels for Highway Runoff (DMRB 4.2) gives guidance and sets out requirements on the hydraulic and structural design of grassed surface water channel for highway drainage. The type of system considered consists of a shallow surface water channel that is lined with grass.

2.17 HA 217 gives guidance and sets out requirements on the design, construction and maintenance of combined surface and sub-surface drains (also called French Drains), where used as a highway drainage system. It also covers the use of topping materials as a safety feature and considers the use of alternative filter materials and the maintenance and rehabilitation of the drain.

3. EFFECT OF ROAD GEOMETRY ON DRAINAGE

Introduction

3.1 Road surfacing materials are generally effectively impermeable, and only a small amount of rainwater should percolate into the pavement layers. Any such water shall be able to drain through underlying pavement layers and away from the formation. Rainfall which does not permeate the pavement surface must be shed towards the edges of the pavement.

Road Geometry

3.2 The consideration of drainage is a basic requirement in the establishment of road alignments and cross-sections which shall ensure that:

a) outfall levels are achievable; and

b) subgrade drainage can discharge above the design flood level of any outfall watercourses.

These considerations may influence the height of embankments above watercourses. They could also influence the depth of cuttings as sag curves located in cuttings must not result in low spots which cannot be drained.

For guidance and requirements relating to the shedding of water from carriageways – refer to TD 9 (DMRB 6.1.1) and TD 16 (DMRB 6.2.3). The following paragraphs summarise good practice advocated in these documents with regard to the interaction of geometry and drainage and therefore the minimum standards of road geometry which the drainage designer would generally expect.

3.3 TD 9 (DMRB 6.1.1) indicates that consideration of drainage of the carriageway surface is particularly important in areas of flat longitudinal gradient and at rollovers. Where longitudinal gradients are low, rollovers should be avoided by adoption of relatively straight alignments with balanced crossfalls.

Drainage can then be effected over the edge of the carriageway to channels, combined surface water and ground water drains or some other form of linear drainage collector. Gullies may be required at very close spacings on flat gradients.

Areas of superelevation change require careful design to ensure that water is shed from the pavement ensure that the water is removed from the pavement as effectively as possible. Where superelevation is applied or removed the crossfall on the carriageway may be insufficient for drainage purposes without assistance from the longitudinal gradient of the road. TD 9 (DMRB 6.1.1) suggests that a net longitudinal gradient of 0.5% should be regarded as the minimum in these cases. The net longitudinal gradient includes the effects of the application of superelevation acting against the gradient where superelevation is:

a) applied on a downhill gradient; or

b) removed on an uphill gradient.

To achieve a net gradient of 0.5% may require a design line gradient of 1.5%. Alternatively the superelevation area may be moved to a different location by revision of the horizontal alignment, or in extreme cases a rolling crown may be applied. A coordinated analysis of the horizontal and vertical alignments with reference to surface water drainage shall be carried out before alignments are fixed. The construction tolerances permissible for road levels must also be taken into account when producing a road surface design that will shed water as effectively as possible. TA 80 (DMRB 4.2) gives further guidance.

3.4 TD 16 (DMRB 6.2.3) provides guidance and requirements on crossfall and longitudinal gradients for carriageway drainage of roundabouts. Roundabouts are designed with limited crossfall to provide smooth transitions and reduce the risk of loads being shed from vehicles turning through relatively small horizontal radii. Consequently areas of carriageways may become inherently flat. Road profiling and the net gradients which result from combination of crossfall and longfall must ensure that water is shed from the pavement as effectively as possible. These may be best indicated by contoured drawings of the required carriageway surface.

Safety Considerations

3.5 Safety aspects of edge details are generally functions of the location, form and size of edge restraint detail, and any associated safety barrier or safety fence provision. Roadside drainage features are primarily designed to remove surface water. Since they are placed along the side of the carriageway, they should not normally pose any physical hazard to road users. It is only in the rare event of a vehicle becoming errant that the consequential effects of a roadside drainage feature upon a vehicle become important. More advice is given in HA 83 (DMRB 4.2).

3.6 Whilst the behaviour of an errant vehicle and its occupants is unpredictable and deemed to be hazardous, the Designer must consider carefully the safety implications of the design and minimise potential safety hazards as far as possible, in the circumstance of a vehicle leaving the carriageway.

The designer shall ensure that the drainage design minimises hazards such as loose drainage fill, that might affect the safety of motorcyclists or non-motorised users in the event of a vehicle leaving the carriageway.

Channel Flow Widths

3.7 The width of channel flow against a kerb face will generally increase in the direction of longitudinal gradient until the flow is intercepted by a road gully, grating or other form of collector.

Design guidance on determination of spacing of road gullies is given in HA 102 (DMRB 4.2): ‘Spacing of road gullies’.

3.8 The acceptable width of channel flow adjacent to a kerb is a site-specific consideration. Factors such as: highway standard, carriageway width, speed limit, lighting, proximity of footway or cycleway, and contiguous width of hard strip or hard shoulder should all be evaluated when proposing an acceptable width for agreement by the overseeing organisation. Guidance on design storms is summarised in paragraph 6.2.

3.9 The design of surface water channels under surcharged conditions are defined in HA 37 (DMRB 4.2).

Surface water channels are formed as an extension to the basic pavement width of a highway, and comprise a triangular or trapezoidal section within which the selected design storm will be accommodated. Storms of greater intensity will surcharge the channel and can be accommodated by permitting a width of flow to encroach onto the adjacent hard shoulder or hard strip. Guidance is given in HA 39 (DMRB 4.2) on the differences in safety considerations consequential to flooding adjacent to the offside lane of a superelevated section of dual carriageway, rather than adjacent to a nearside lane.

Surface Drainage of Wide Carriageways and at Merges and Diverges

3.10 Guidance is given in TA 80 (DMRB 4.2) on the design of drainage for wide carriageways and for junction areas and changes of superelevation. Where a slip road or main carriageway crossfalls towards the nose of a merge or diverge section of an interchange or junction, it will be necessary to provide drainage within the nosing.

3.11 Such drainage should intercept all runoff which would accumulate in the nosing or flow across the nosing onto an adjacent pavement. This can be effected by a longitudinal grated or slotted linear drainage channel, or by road gullies within a suitably dished cross-section of the nosing.

3.12 Such drainage installations must be safe and structurally adequate to allow for not just errant vehicles but also usage which may occur during temporary traffic management and the trafficking of hard shoulders. Ensure that the structural strength of drainage installations is appropriate to withstand applied loading in respect of abnormal load routes.

4. SURFACE WATER COLLECTION: EDGE DRAINAGE DETAILS

Introduction

4.1 Surface water runoff from the edges of UK roads is generally collected by kerbs and gullies, combined kerb and drainage blocks, surface water channels and channel blocks, linear drainage channels or by direct runoff into combined surface and subsurface drains adjacent to the pavement edge.

4.2 The DMRB deals in some detail with kerbs and gullies, surface water channels, both concrete and grassed, channel blocks, combined channel and pipe systems, and combined surface and subsurface drains. Guidance upon their application is set out in TA 57 (DMRB 6.3), HA 37 (DMRB 4.2), HA 39 (DMRB 4.2), HA 102 (DMRB 4.2), HA 113 (DMRB 4.2) and HA 119 (DMRB 4.2). Use of combined kerb and drainage systems requires that performance requirements be set out by the designer as a result of his or her design calculations in numbered contract specific Appendices 1/11 and 5/5 to the Specification (MCHW 2) and must be given in terms of performance – identifying any site specific constraints. Linear drainage channels comprise closed conduits into which water drains through slots or gratings in the tops. Combined channel and pipe systems comprise surface water channels having an internal pipe formed within the base of the units that is able to carry additional flow.

4.3 Each of these alternative modes of drainage is dealt with in more detail later in this Standard. General applications of their usage are shown in Table 4.1. Recommended design selections from the various alternatives for verge and central reserve situations respectively are illustrated diagrammatically in Figures 4.1 and 4.2.

4.4 Advice on the location and design of outfalls and culverts is given in HA 107 (DMRB 4.2), and guidance on soakaway design can be found in HA 118 (DMRB 4.2). Considerations of detention storage and specific pollution control measures (to ensure the risk of flooding and pollution are contained within levels acceptable to the Overseeing Organisation) may influence selection of drainage solutions and are described later in this Standard. Advice on vegetated drainage systems is given in HA 103 (DMRB 4.2).

Kerbs and Gullies

4.5 Road surface drainage by kerbs and gullies is commonly used in the UK, particularly in urban and embankment conditions. Gully connection pipes discharge to outlet generally via a junction with longitudinal carrier pipes set within the verge. The function of kerbs is not purely to constrain edge drainage. They provide some structural support during pavement laying operations and protect footpaths and verges from vehicular overrun.

4.6 An indirect hazard to vehicles can be presented by edge details that permit adjacent build-up of widths of water flow, which may intrude into the hard shoulder, hard strip or carriageway of the highway. This can occur with edge details that do not immediately remove water linearly from the adjacent pavement in all storm situations. The edge detail to which this problem is most pertinent is the raised kerb detail commonly used on urban roads. Functioning of kerb and gully systems is dependent upon the build up of a flow of water in front of the kerb. Gully spacings will be set out to suit an acceptable width of flow for the design storm as set out in paragraphs 3.7 and 3.8.

4.7 One advantage of kerbs and gullies is that a longitudinal gradient to carry road surface runoff to outlet is not dependent upon the longitudinal gradient of the road itself, and can be formed within a longitudinal carrier pipe. Different types of gully are available that provide for varying degrees of entrapment of detritus.

4.8 Road gullies will generally discharge to associated longitudinal carrier drains except on low embankments with toe ditches where it may prove more economical to discharge gullies direct to the toe ditches via discrete outlets. Fin or narrow filter drains would drain the pavement layers and formation in such instances.

4.9 Cuttings with high ground water flows (HA 39, DMRB 4.2) will require conventional deep filter drains instead of fin or narrow filter drains. It is often difficult to provide a filter drain and a separate carrier drain to collect gully connections within a normal verge width.

In such circumstances there is justification for the adoption of combined surface water and ground water drains. Where gullies are required connections should only be made directly into junction pipes. Pipe types permitted for the carrier drains must be able to accommodate this requirement.

Surface Water Channels

4.10 Surface water channels are normally of triangular concrete section, usually slip-formed, set at the edge of the hard strip or hard shoulder and flush with the road surface. They are the preferred edge-detail solution on the UK motorway and all-purpose road network, and their usage is described in HA 39 (DMRB 4.2).

4.11 Significant benefits can include ease of maintenance and the fact that long lengths, devoid of interruptions, can be constructed quickly and fairly inexpensively. It may be possible to locate channel outlets at appreciable spacings and possibly coincident with watercourses. However carriageways with flat longitudinal gradients may necessitate discharge of channels fairly frequently into outlets or parallel longitudinal carrier pipes in order to minimise the size of the channels. It will probably be found most economic to design surface water channels such that outlet spacings in the verges are coincident with cross-carriageway discharges from the central reserve.

4.12 The relative risk to vehicles and occupants from impingement on surface water channels may be said to be lower than would be expected from impingement on other drainage features such as kerbs, embankments and ditches, as the channels present a much lower risk of vehicles losing contact with the ground or overturning.

Drainage Channel Blocks

4.13 Guidance and requirements on the use of Drainage Channel Blocks is also set out in HA 39 (DMRB 4.2). These are smaller in section than surface water channels and are not permitted as edge drains contiguous with hard shoulders, hard strips or carriageways in order to collect direct runoff from those elements of the highway.

4.14 There are potential maintenance difficulties associated with the use of drainage channel blocks and the designer will need to assess the likelihood of these factors when deciding whether to use them:

i) any settlement of adjacent unpaved surfaces would reduce their effectiveness;

ii) they may be prone to rapid build up of silt and debris in flat areas; and

iii) grass cutting operations by mechanical plant will be jeopardised adjacent to the channel.

Some roads are drained by ‘grips’ which comprise shallow channels excavated across verges to allow drainage from road edges to roadside ditches. These suffer many of the same disbenefits. Grips and channel blocks should be avoided in verges subject to frequent usage by equestrians or other vulnerable users.

Combined Kerb and Drainage

4.15 Combined kerb and drainage systems are precast concrete units either in one piece or comprising separate top and bottom sections. A continuous closed internal channel section is formed when contiguous blocks are laid. The part of a unit projecting above road level looks similar to a conventional kerb unit though the face has a series of preformed holes that admits water into the internal cavity.

4.16 They are especially useful where kerbs are necessary at locations of little or no longitudinal gradient, particularly at roundabouts where their linear drainage function removes the need for any 'false' crowning of road-edge channels. They can be useful where there are a number of public utility services, especially in urban areas. They may be economic in rock cuttings, if the high cost of carrier drain installation in such situations can be thereby avoided.

Linear Drainage Channels

4.17 Linear Drainage Channels can be manufactured or formed in situ. Manufactured units may be of concrete, polymer concrete, glass reinforced concrete or other material. They are in all cases set flush with the carriageway and contain a drainage conduit beneath the surface into which surface water enters through slots or gratings. They can also be of in situ concrete. Manufactured units have been commercially available for many years, but in situ construction has been adopted much more recently in the UK. When used on shallow gradients they may be prone to maintenance difficulties as described in paragraph 3.13. Advice may be sought from the Overseeing Organisation on current experience in maintaining these systems.

Combined Channel and Pipe Drains

4.18 These are similar to surface water channels, with the addition of a pipe formed within the system. This provides extra flow capacity for a channel of the same width, reducing the number of outlets from the system and reducing, or even eliminating the need for a separate carrier pipe. Where space is limited (for example, in road widening schemes) they allow a narrower channel to be built than would otherwise be possible.

This system is described in HA 113 (DMRB 4.2) and may be used wherever surface water channels would be suitable. Like surface water channels, they are particularly suited to in situ construction in concrete using slip forming techniques. Where they are used in situations that require sub-surface drainage of the pavement, the sub-surface drain will be located between the pavement construction and the channel, as the latter will form a barrier to the horizontal movement of moisture at the pavement edge. This is different from usual practice for solid surface water channels.

Informal Drainage (Over the Edge)

4.19 This method of drainage, applicable to embankment conditions, is illustrated in MCHW 3 B13, and its usage is described in HA 39 (DMRB 4.2). It is inappropriate for usage in locations where footways or segregated cycleways abut carriageways, on structures or on embankments constructed on moisture susceptible soils. Uncontrolled growth on verges can inhibit free drainage.

Grassed Surface Water Channels

4.20 Grassed channels are a development of swales for use as road edge channels. They have gentle slopes and are often combined with over-the-edge drainage or combined surface water and ground water drains. They are becoming increasingly common due to their potential to control both storm water runoff rates and pollution. HA 119 (DMRB 4.2) gives advice on their suitability and design. Their ability to treat pollution is given later in Table 8.1.

Effects of Pavement Overlays on Drainage Edge Details

4.21 Overlays require raising of verge and central reserve levels, with the following respective implications:

i) Kerbs and gullies and combined surface and sub-surface drains

Necessary associated drainage works comprise bringing up of filter media and gully gratings to new levels. Neither of these activities presents any great difficulty. Alteration to the levels of precast concrete kerbs is more difficult and expensive than the removal and replacement of extruded asphalt kerbing, but is a matter beyond considerations of drainage detail. It may be advisable to evaluate the relative economics of an alternative solution comprising reconstruction of the adjacent pavement.

ii) Surface water channels

Raising of surface water channels may be avoidable if the edge of the overlay can be shaped to suit the top of the channel without compromising the structural integrity of the pavement. Alternatively the existing channel could be broken out and replaced at a higher level. This latter solution would be much more expensive, requiring remedial attention to local breakout of the surfacing and base course consequential to removal of the existing channel. There would also be a temporary loss of drainage facility at the carriageway edge if the channel was constructed prior to placement of the overlay.

Porous Asphalt Surfacing Course

4.22 HD 26 (DMRB 7.2.3) and HD 27 (DMRB 7.2.4) set out the standards for the usage of porous asphalt. Advice on appropriate edge of pavement details is contained in HA79 (DMRB 4.2.4) and further guidance on their usage may be sought from the Overseeing Organisation.

Porous asphalt is an appropriate surface material for permitting the inflow of water into a Reservoir Pavement where this drainage system is permitted by the Overseeing Organisation.

Drainage Collector Detail	Kerbs and Gullies (See Note 1)	Combined Kerb and Drainage System	Linear Drainage Channels	Surface Water Channels	Combined Channel and Pipe Drains	Combined Surface and Sub-surface Drains	Informal Drainage (Over the Edge)	Grassed Surface Water Channels
Urban Applications	General usage	Congested public utility services Shallow outlets Flat long. gradients	Car park areas Adjacent to vertical concrete barriers Nosings of interchanges	Not generally applicable	Not generally applicable	Not generally applicable	Not generally applicable	Not generally applicable
(Reference documents)	(TA 57) HA 102 HA 104 HA 105		TA 80 HA 78					
Rural Applications	Footways within highway verge eg laybys Roundabouts	Flat long. gradients where footways within highway verge Roundabouts	Nosings of interchanges vertical concrete barriers	High-speed roads especially on embankments	High-speed roads especially on embankments where verge space is limited	Especially in cutting verge	In verges (not suitable for embankments constructed of clayey or silty soil)	In verges
(Reference documents)	(See Note 2) (TA 57)		TA 80 HA 78	TA 80 HA 78 (HA 39) HA 37	(HA 113)	HA 217 (HA 39)	(HA 39) (HA 103)	(HA 119)

Notes:

1 Kerbs in this context are precast concrete, for the necessary strength and resistance to high speed impact at a reasonable cost.

2 Kerbs and gullies are not recommended for rural roads unless footways are located within the verge, or safety barriers or parapets are required or continual surface and sub-surface drains are present, as in rural situations the drainage will generally be 'over the edge' to drainage ditches – as a more cost effective and easier to maintain solution.

Table 4.1: tGeneral Applications of Edge Drainage Details

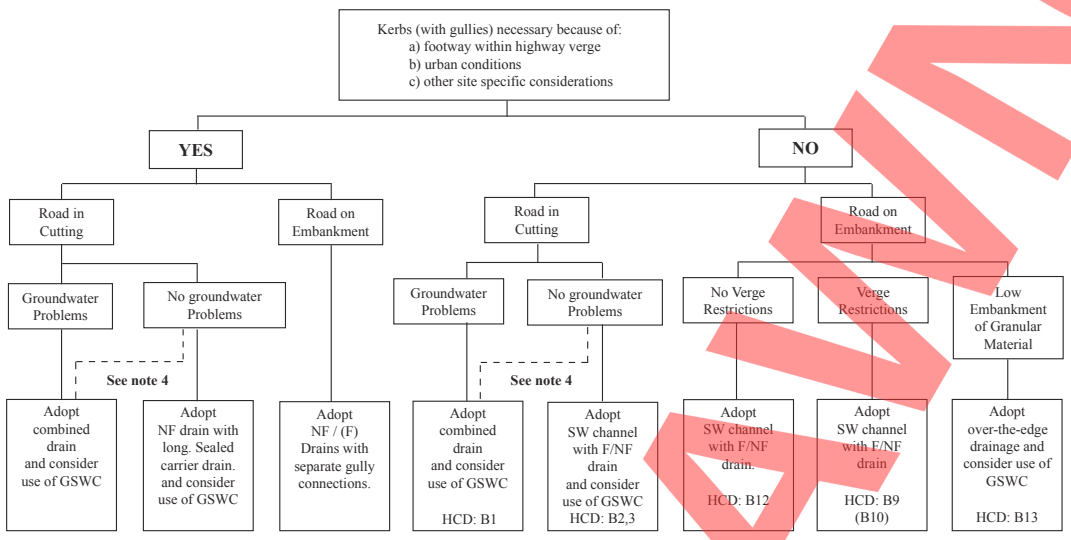

Figure 4.1: Recommended Design Selection Verge-Side Edge Drainage

Note 1: Fin drain usage denoted thus (F) indicates use with road gullies, and should only be permitted if gully connections have no adverse effect on fin drain.
Note 2: NF denotes alternative Narrow Filter Drain.
Note 3: Turf edging between intermittent precast concrete kerb/gully combinations may be acceptable on minor rural roads.
Note 4: This solution can be useful where lack of space inhibits provision of a separate carrier drain + F/NF trench.
Note 5: GSWC denotes Grassed Surface Water Channel.
Note 6: This selection approach has been developed considering the relative costs of the different solutions and their associated maintenance implications.

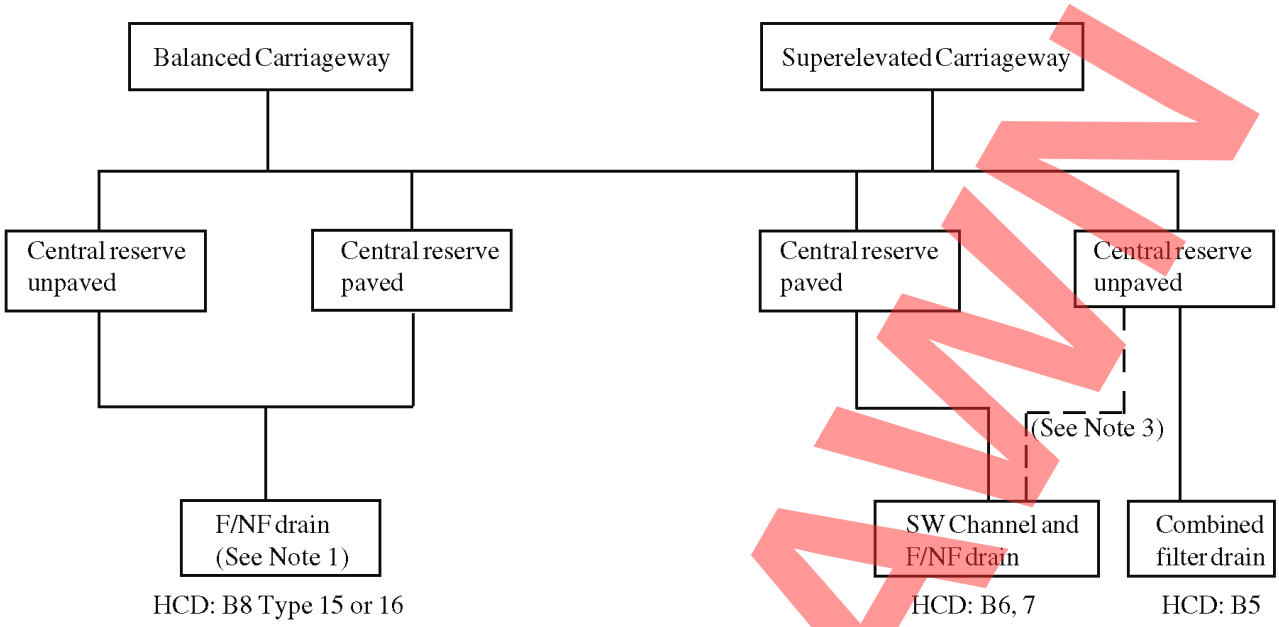

Figure 4.2: Recommended Design Selection Central Reserve Drainage

Note 1: A detail like HCD: B8 Type 14 may be judged preferable for the drainage of wide central reserves.
Note 2: F/NF denotes Fin or Narrow Filter Drain.
Note 3: This is the preferred solution.

5. SUB-SURFACE DRAINAGE

Introduction

5.1 Sub-surface drainage of highway pavements comprises the measures incorporated in the design in order to control levels of groundwater, and drain the road foundation (see HD 25, DMRB 7.2).

5.2 Requirements for sub-surface drainage are illustrated in Highway Construction Details, MCHW 3. Sub-surface drainage is normally necessary in order to remove any water which may permeate through the pavement layers of roads in both cut and fill situations. This can be achieved on embankments by provision of fin or narrow filter drains illustrated in the B and F Series Drawings of MCHW 3.

5.3 Sub-surface drainage in cuttings must provide not only for the necessary drainage of pavement layers, but also for the removal, to an adequate depth, of any groundwater which may be present in the cutting.

5.4 Groundwater may be subject to seasonal variations consequential to rainfall conditions and soil permeability, and the best possible analysis of groundwater conditions should be undertaken during ground investigation. Water moves partly by gravity and partly by capillary action, and these movements are susceptible to control by subsoil drainage.

5.5 Sub-surface drainage is effected by installation of longitudinal sub-surface drains at the low edges of road pavements. These serve to drain the pavement layers and the pavement foundation. They also prevent ingress of water from verge areas adjacent to the pavement.

5.6 Water shall not be retained within the sub-base or the capping layer. Water reaching the formation and sub-formation shall be drained to longitudinal sub-surface drains by adequate shaping of the formation and sub-formation such that no undrainable low spots occur.

5.7 Circumstances in which sub-surface drainage may be omitted are described in HD 25 (DMRB 7.2) and HA 39 (DMRB 4.2), but advice should be sought from the Overseeing Organisation in such instances.

5.8 Table 5.1 sets out the documents which give guidance on the provision of sub-surface drainage. MCHW 3 indicates alternative acceptable sub-surface drains in cross-section, and MCHW 1, in conjunction with numbered Appendix 5/1, specifies acceptable construction materials. Implications are dealt with in detail in the text following.

Groundwater Considerations

5.9 HA 44 (DMRB 4.1) advises upon CBR values of subgrade and capping relative to sub-surface drainage conditions. Weak cohesive subgrade material in cuttings will require replacement by a capping layer, and the CBR value used to determine the required capping layer thickness required will have been chosen for a particular water table level. That level will eventually be dependent upon the depth of the subgrade drains below sub-formation level. HA 44 (DMRB 4.1.1) enables CBR values to be assessed for two conditions of water table level, a 'high' water table of 300mm below formation or sub-formation level, and a 'low' water table of 1000mm below formation or sub-formation level.

5.10 The minimum depth of installation of fin and narrow filter drains is shown in the detail in MCHW 3 relative to formation level, or sub-formation level: as defined in clauses 601.9 and 601.10 (MCHW 1). Where there is no capping layer, the design should require the drains to be laid to the lower of those two depths. Drains installed at these minimum depths cannot lower high groundwater to even the 'high' water table level of 300mm below sub-formation level. In some instances, to achieve even the 'high' water table level will

require the fin or narrow filter drains to be installed at an appreciably greater depth than the minimum shown in MCHW 3.

5.11 In situations where large volumes of groundwater are anticipated filter drains can provide a better solution than fin or narrow filter drains.

5.12 A further consideration is that a fin or narrow filter drain will normally follow the longitudinal profile of the carriageway and therefore it is essential to ensure that the drains shall be able to discharge from all low points of the fin or filter drain to a suitable outlet.

These are additional considerations in assessing the applicability or otherwise of fin and/or narrow filter drains rather than combined surface and subsurface drains.

Sub-surface Drainage of Roads in Cuttings

5.13 The general principles of highway drainage are that surface water be kept separate from sub-surface water in order to prevent large amounts of water being introduced into the road pavement at foundation level. It may not always be possible to achieve this. For example, in the case of cuttings there are many benefits that can accrue from the provision of combined surface and subsurface drains. These include:

i) permissible early installation and usage for collection of drainage runoff during the construction stage, provided construction debris is prevented from blocking the filter media. This could be done, for example, by the use of temporary sedimentation ponds;

ii) removal of groundwater beneath the pavement to a greater depth than would be possible with fin or narrow filter drains;

iii) easier construction than with a solution incorporating both surface water carrier drains and fin or narrow filter drains;

iv) easier inspection and maintenance than is possible with fin or narrow filter drains;

v) facility for collection of water from drainage measures installed separately in the side-slopes of cuttings.

5.14 Combined surface and subsurface drains in cuttings may be constructed using pipes with perforations or slots laid uppermost, and with sealed joints to minimise surface water input at trench base level. Trench bottoms may need to be lined with impermeable membranes up to pipe soffit level to prevent addition of water to the sub-soil that may otherwise be dry.

Sub-surface Drainage of Roads on Embankment

5.15 Drainage of pavement layers of roads on embankment is effected by fin or narrow filter drains contiguous to the edge of the pavement as shown in the B-Series Drawings of MCHW 3, and as explained in HA 39 (DMRB 4.2).

Relative Characteristics of Combined and Separate Systems

5.16 HA 39 (DMRB 4.2) requires that restraints imposed upon any choice of drain types should be minimised in order to encourage cost-effective solutions. It does, however, accept that particular types of drains or material may be excluded for sound engineering reasons.

5.17 The differences in principle between combined and separate highway drainage systems are given in paragraph 1.7 of the Introduction to this Standard. These differences are described in greater detail in the following text.

5.18 A combined system comprises porous, perforated or open jointed non-porous pipes within trenches backfilled with permeable material. These trenches are situated in verges and/or central reserves adjacent to the low edges of pavements such that surface water can run off the pavement directly onto the trench top and then permeate through the drain trench backfill to the drain pipe at the base of the trench. Pavement and capping layers are contiguous with the side of the trench, and any water within these layers is also collected by the drain. Such drains contain a number of variables, primarily pipe types, filter drain backfill material, trench top surfacings and use of geosynthetic membranes and/or impermeable trench treatments as necessary in special cases. The function of the drain with respect to surface water runoff and sub-surface drainage remains identical in all cases. They also have considerable capacity to facilitate the lowering of groundwater and collection of slope drainage from cuttings.

5.19 Separate systems provide for collection of sub-surface water i.e. drainage of pavement and capping layers, separately from that of surface water runoff from the pavement. The surface water can be collected by several different systems such as surface water channels, combined kerb and drainage system, road gullies and linear drainage channels. Sub-surface drainage associated with separate collection of surface water runoff is effected by either fin or narrow filter drains defined in MCHW 1 and MCHW 3 F18

Combined Surface and Sub-surface Drains

5.20 Combined surface and sub-surface drains – as a solution for highway drainage – have been in use for many years. This practice has helped to identify potential issues that were previously not fully understood. These include stone scatter, surface failures of embankments, pavement failures and safety and maintenance problems. Stone scatter from verge drains, where a hard shoulder of 3.3m width separates the verge from the carriageway, may not normally be a problem, but may present a safety hazard when the hard shoulder is used as running lane. Stone scatter from central reserve drains also presents a safety hazard. Guidance on surface stabilisation techniques for filter drain materials to reduce hazards is contained in HA 217 (DMRB 4.2.4) and is summarised below

Problems can be reduced by implementation of any of the following measures:

i) spraying of the top surface of exposed filter material with bitumen;

ii) the use of geogrids to reinforce the surface layer of the filter material;

iii) incorporation of lightweight aggregate for filter material at finished level, as permitted in MCHW 3 B15;

iv) possible usage of bitumen bonded filter material in the top 200mm of the trench.

5.21 Combined surface and sub-surface drains can be advantageously employed in cutting situations requiring appreciable ground water removal. The relatively large hydraulic capacity required for dealing with surface water during heavy storms means that combined drains generally contain sufficient capacity to take any intercepted ground water. Separate design estimates of groundwater flows are not generally necessary.

5.22 Problems may arise with porous concrete pipes used in filter drains. These have lower structural strength than other rigid pipes and their adoption must be checked against this criteria and local experience.

Separate System: Fin Drains

Types 5, 6 and 7 Fin Drains

5.23 Detailed guidance is given in Series NG500 (MCHW 2). It is intended that the widest possible choice of fin drain type should be available to the Contractor.

5.24 It is intended that types 5, 6 and 7 drains be installed in narrow trenches and there can be difficulties in working in very narrow trenches, depending on the type of ground, and in compaction of backfill.

These problems should be alleviated by the use of automatic drain-laying equipment where ground conditions permit. Non-granular materials will permit excavation by continuous trenching machine, provided that the trench remains open sufficiently long for the drain to be installed. In suitable granular materials, installation can be effected by plough and simultaneous drain installation by following 'box'. Associated hoppers and chutes can place backfill where necessary. Neither of these techniques is suitable for use in coarse non-cohesive materials such as rock capping layer. Installation by open trench may be unavoidable in such materials.

5.25 If it is proposed to use fin drains in conjunction with kerbs and gully pavement edge drainage, the design layout and details for construction of gully connections shall not prejudice the integrity of the fin drains. The implications of non-restriction in construction trench width of a Type 5 fin drain should be considered. Consequences of the possible unsuitability of trench arisings as backfill material should also be considered and appropriate backfill specified.

Type 10 Fin Drain

5. 26 HA 39 (DMRB 4.2) specifies use of a Type 10 drain with rigid carriageways. The designer should decide whether particular scheme specific pavement materials, in particular thin surfacing materials (refer to B series of MCHW3), warrant its adoption with flexible construction.

Separate System: Narrow Filter Drains

5.27 Narrow filter drains are intended for use as edge of pavement sub-surface drains and are suitable alternatives to fin drains for that purpose. Guidance is similar to that for fin drains, in MCHW 2, but in addition requires that for Type 8 drains 'the filter materials should be compatible with the adjacent soil or construction layer as the filtration is achieved by the filter material and the geotextile sock around the pipe'. This can be difficult to predict, particularly in the upper layer of embankments. Use of 100mm dia pipes within narrow filter drains, rather than pipes of smaller diameter, should provide benefits with respect to future maintenance and at little or no additional cost.

Pavement Life

5.28 There are factors pertinent to drainage at construction stage that have a bearing upon the life of a pavement. During construction, poor control of soil moisture content, due to surface water ingress, can lead to plastic deformation of the road foundation, sub-base and capping layer. To minimise the risk of such deformation occurring, appropriate pre-earthworks groundwater drainage and sub-grade drainage should be constructed. The CBR should not be allowed to reduce from its assumed long term equilibrium to an unacceptable one as a consequence of softening due to the presence of water. HD 25 (DMRB 7.2) defines requirements of the road foundation. Groundwater drainage and sub-grade drainage minimises the risk of plastic deformation of the road foundations, sub-base and capping layer during construction due to poor control of moisture content. Where whole-life cost and / or programme benefits can be demonstrated then pre-earthworks drainage should be investigated with the agreement of the overseeing organisation.

MCHW	DMRB			NMM (Only applicable in England)
Vol 1: Specification 500 – Series	**VOL 4: GEOTECHNICS AND DRAINAGE**		**VOL 7: PAVEMENT DESIGN AND MAINTENANCE**	**PART 3: ROUTINE SERVICE**
Vol 2: Notes for Guidance 500 – Series 600 – Series	**SECTION 1: EARTHWORKS**	**SECTION 2: DRAINAGE**	**SECTION 2: PAVEMENT DESIGN AND CONSTRUCTION**	Chapter 3.3 Drainage
Vol 3: HCD B – Series F – Series	**Part 1: HA 44 Design and Preparation of Contract Documents** Chapter 7 Cuttings: Groundwater Chapter 8 Embankments: Drainage Chapter 10 Sub-grade and Capping: Drainage (paras 25-27) **Part 3: HD 41 Maintenance of Highway Geotechnical Assets** 1. Introduction: General (paras 1.1 & 1.2)	**HA 39 Edge of Pavement Details** Sub-surface drainage (para 3.8) **HA 40 Determination of Pipe and Bedding Combinations for Drainage Works** HA 217: Alternative Filter Media and Surface Stabilisation Techniques for Combined Surface Water and Ground Water Drains	**Part 2: HD 25 Foundations** Chapter 2 Subgrade Assessment Chapter 3 Capping and Sub-base (paras 3.27-3.32)	

Table 5.1: Sub-Surface Drainage – Guidance Documents

6. EARTHWORKS DRAINAGE

Toe Drainage and Cut-off Drains

6.1 Existing land drainage and runoff from external catchments shall be taken into account in the design of highway drainage. See HA 106 (DMRB 4.2) for specific advice.

The requirements of the appropriate water and drainage authorities shall be established to ensure that their rights are accommodated and their reasonable interests safeguarded. Information on ground water conditions shall be included in the data obtained from site investigations for proposed roadworks.

6.2 All run off from the existing land drainage system must be kept entirely separate from the highway drainage systems and surface water from the external catchment must not be discharged into the highway drainage system.

Where it is not possible to avoid surface water and sub-surface water from adjoining land flowing towards the road, it will generally be necessary to construct intercepting drains at the tops of cuttings and the toes of embankments. In rural areas these may be ditches rather than filter drains because of their greater capacity and comparatively lower cost.

Where there is an existing connection of external drainage to the highway drainage, either historical or by agreement, the right to connection may be permitted to continue by the Overseeing Organisation provided that the land use of the contributing catchment of the connection remains unaltered. The agreement of the Overseeing Organisation must be secured in advance of construction.

New surface water connections from sites and/or proposed developments adjacent to the road must not be accepted.

6.3 The effect on stability of embankments and cutting slopes of any proposed ditches shall be assessed at an early stage in design by a Geotechnical Engineer, as large offsets may be necessary from the toes of embankments to associated toe-ditches. This may affect land acquisition requirements in the draft Compulsory Purchase Order (CPO) for a scheme. It may also affect adjacent land management and the choice of drainage solution. Landscaping measures, especially the inclusion of noise bunds, may influence drainage design.

6.4 It is good practice to carry out drainage works at the earliest possible stage in the construction of any new road. The drainage design is to be completed at an early stage of scheme design whenever possible. Longitudinal drains should be sufficiently deep to collect whatever drainage is necessary at cut/fill zones and it will be necessary to collect and treat, using sub-soil drains, water from any water-bearing seams which are intercepted by any new cuttings. Intercepting drains or ditches shall be sufficiently deep to intercept any system of severed agricultural under-drainage.

6.5 Watercourses and ditches crossed by highways are generally bridged or culverted, with the consent of the relevant land drainage authority. HA 106 (DMRB 4.2) provides specific advice on dealing with the drainage of natural catchments and HA 107 (DMRB 4.2) gives detailed advice on outfall and culvert provision.

6.6 Where it is necessary to provide slope drainage in cuttings a longitudinal piped drainage system shall be provided in the verge. This will be additional and initially separate to the pavement drainage system and help to collect water from the slope drains without any detrimental effect on sub-surface drainage of the pavement. A drainage system comprising a surface water channel with an associated fin or narrow filter drain, and no longitudinal pipe drain, could not be used to collect slope drainage. It would be necessary to

provide, in addition, a longitudinal carrier drain, or dispense with the fin or narrow filter drain and provide a filter drain, or alternatively use a combined surface and sub-surface drain without a surface water channel.

6.7 The need for slope drainage should be determined early in the design process and where it is required – the longitudinal elements installed prior to the start of other construction works - in order to minimise difficulties in the future connection of slope drains into longitudinal verge drains.

Drainage to Retaining Structures

6.8 Requirements for drainage of retaining structures are set out in BD 30 (DMRB 2.1).

7. DETAILED DESIGN, PAVEMENT EDGE DRAINAGE

Introduction

7.1 Detailed design of pavement drainage involves the identification of options and the recommendation of the option that suits the project constraints. This comprises six basic aspects:

i) determination of the design storm that should be used in the design of the drainage elements within the catchment under consideration;

ii) calculation of the flows from the design storm at each drainage element within the catchment;

iii) establishment of the hydraulic adequacy of each drainage element within the catchment;

iv) determination of the location of the outfalls or soakaways; and

v) determination, where necessary, of structural loadings upon drainage conduits, and verification that each conduit will withstand the loading placed upon it; and

vi) identification of pollution and flood risks and the means to address them (see Chapter 8).

Storm Return Period

7.2 Longitudinal sealed carrier drains shall be designed to accommodate a one-year storm in-bore without surcharge. The design shall be checked against a five-year storm intensity to ensure that surcharge levels do not exceed the levels of chamber covers.

Combined surface water and ground water drains shall also be designed to accommodate a one-year storm in-bore without surcharge. A design check shall be carried out to establish that a five-year storm intensity will not cause chamber surcharge levels to rise above the formation level, or sub-formation level where a capping layer is present. In carrying out this check it should be assumed that pipes are sealed and that back flow from pipes into the filter media does not take place.

7.3 Guidance on the design of surface water channels is given in HA 39 (DMRB 4.2). The principle for the design of channels is that a design storm with a return period of one year must be contained within the channel, and that surcharge consequential to a storm of five-year return period should not encroach into the running lane.

Channels must be designed to accommodate a 1 in 1 year storm with the flow contained within the channel cross section without surcharging. The allowable surcharge widths must then be checked for 1 in 5 year storm.

In verges, surcharges under a 1 in 5 year storm must be limited to a width of 1.5m in the case of hard shoulder and 1.0m in the case of hard strip.

In central reserves, surcharge under a 1 in 5 year storm must not be permitted to encroach the carriageway, but flooding within the non-pavement width of the central reserve is permissible providing there is safeguard against flows from the surcharged channel overtopping the central reserve and flowing into the opposing carriageway.

Allowance for climate change:

7.4 The rainfall intensities used to calculate the design storms must include an allowance for the effects of climate change. Where rainfall data exclude such an allowance, a sensitivity test on the design of the drainage system must be carried out by increasing rainfall intensities of the design storm by 20% and adjustment made to the design should the initial design fail this sensitivity test.

7.5 Application of storms of other return periods shall be influenced by considerations of geography and particular highway geometry. Examples of critical sections of road are quoted in HA 37 (DMRB 4.2) as:

i) applications of superelevation that cause crossfall to be locally zero;

ii) sections of road draining to longitudinal sag points where it is important to prevent flooding; and

iii) longitudinal sags in cuttings, where it may for example be deemed prudent to design outlet drainage to a design storm return period of say ten years (i.e. having an annual probability of 10%).

These are matters for engineering judgement relative to the drainage elements under consideration, and the consequences of surcharge of the system in its unique situation which require a risk assessment to be undertaken and appropriate design alterations made in relation to the findings of such a risk assessment.

Calculation of Runoff Flows

7.6 Having determined the relevant design storm frequency that should be used, it is necessary to determine the storm that will give maximum runoff at the various locations within the catchment.

7.7 Over the years, drainage designers have been using a number of established procedures (ref. 9) for calculating runoff. However, the most commonly used procedure in the UK is the Wallingford Procedure first published in 1981 (ref.11). This comprises a number of methods and one of these, the Modified Rational Method, gives a value of peak discharge only and no indication of runoff volume or hydrograph shape. It is recommended within the Wallingford Procedure that catchments to be analysed by this Method should not exceed 150 hectares, with times of concentration of up to about 30 minutes and outfall pipe diameters of up to about one metre.

The Wallingford Hydrograph Method is a computer-based hydrograph method incorporating separate models of the surface runoff and pipe-flow phases. Storm overflows, on-line and off-line tanks and pumping stations may be represented. The Method is appropriate to the majority of applications. Peak flow discharges obtained by the Modified Rational Method and Wallingford Hydrograph Method are of comparable accuracy. Data input requirements are similar for both methods.

7.8 A number of commercial programs based upon the Wallingford Procedure are available and suitable for highway drainage design. Programs selected for use should be able to design a system to a particular storm intensity, and permit analysis of the system under surcharged conditions. Details of these programs and their use are given in HD 45 (DMRB 11.3.10).

Those responsible for the design of drainage systems shall be responsible for the choice of methods used for the analysis and design of drainage systems and satisfy themselves that the methods chosen are appropriate for the system

Gully Systems

7.9 Gully systems are based upon the collection, by road gully, of surface water runoff which has been shed towards the edges of a road pavement and which flows along a road channel in front of a raised kerb until it is collected by a gully.

The spacing of road gullies is related to the maximum width of flow that can be permitted in a channel fronting a raised kerb. Advice on gully design spacing is given in HA 102 (DMRB 4.2) Performance requirements for gulley gratings shall be determined as part of the design and included in the contract specific Appendix 5/1, and the comments in 6.9 are pertinent to structural considerations of traffic loadings to which gullies are subject.

7.10 The nosing sections of junction merge and diverge tapers commonly have low points in cross-section due to the direction of crossfalls of the slip roads and main carriageways and because of similar corresponding channel levels. Drainage elements placed within these tapers must be designed to withstand trafficking of the hard shoulder.

Surface Water Channels

7.11 Design of surface water channels is described in principle in HA 39 (DMRB 4.2). Design of the channels in cross-section to achieve the necessary hydraulic capacities is set out in HA 37 (DMRB 4.2); example cross-sections are illustrated in the MCHW Volume 3, Section 1 B Series Drawings. The design technique is essentially a method by which the required size or distance between outlets for channels is determined taking into account local rainfall characteristics.

7.12 Surface water channels generally occupy a larger proportion of the available verge or central reserve width than do other common drainage systems. This is particularly the case for wide motorways with a verge width of 1.5 metres, where transverse areas of impermeable pavement are proportionately larger and the unpaved width of verge much less than that of trunk roads. Other features within verges and central reserves such as safety fences, services, lighting columns and signs impose further restrictions upon maximum channel sizes which can be constructed. The achievement of long channel lengths may also be prevented by necessary discontinuations at piers, abutments, slip roads, junctions, laybys, central reserve crossover points or emergency crossing points. Changes of superelevation also constitute points of termination of channels. The surface drainage of wide carriageways is described in TA 80 (DMRB 4.2).

7.13 It is necessary to outlet surface water channels whenever they reach capacity, and if suitable outlets are not available carrier pipes become necessary. Discharge into carrier pipes will be unavoidable in cuttings more than a few hundred metres in length. When discharge into a longitudinal carrier pipe has become necessary, access chambers are required at a maximum of 100m intervals or as determined in accordance with HA 78 (DMRB 4.2). These provide convenient discharge points for channel outlets via suitable aprons and gratings within the channel invert. They also enable incorporation of smaller channel sections that can be more easily accommodated within the available highway cross-section.

7.14 The design method of HA 37 (DMRB 4.2) is based on kinematic wave theory and takes account of variations in rainfall and flow conditions with time. For the purpose-built surface drainage channels, HA 37 (DMRB 4.2) should be used to determine the spacing between the outlets, which, in turn, should be designed according to the recommendations of HA 78 (DMRB 4.2).

Combined Kerb and Drainage System

7.15 Combined kerb and drainage blocks were commented upon in principle in Chapter 3. The Designer is required to determine and describe the essential characteristics of the drainage system for the particular

location. Such characteristics include the dimensions and strength of the units and their hydraulic design parameters. The contractor shall design the system. The designer should obtain the approval of the Overseeing Organisation to the content and inclusion of the Specification which he requires. Proprietary combined kerb and drainage units should be examined, and in the interests of commercial benefit the specification should be as wide as possible to maximise competition. The designer's attention is drawn to instances where this system has been damaged by repeated vehicle over run and should evaluate the risks of such damage on a site by site basis.

7.16 Each manufacturer produces comprehensive literature of the product and this will include statements and a design guide to the hydraulic capacity of his product. The designer should be aware that the claimed hydraulic capacities may have been derived on a simplistic basis, normally based on the Colebrook-White equation for open-channel flow. The effect of turbulence from the entry of flow at each inlet to the blocks will be detrimental to the flow conditions and may or may not have been taken into account. For several reasons an equable comparison of the relative practical performance of kerbs and gullies, surface water channels and combined kerb and drainage is not possible. Different flow theories are used in each case, the most extreme disparity being that part flooding of the carriageway is accepted in the operation of a kerb and gully system, whilst no such flooding is taken into account in manufacturers' claims for capacities of combined kerb and drainage blocks. The designer will need to be satisfied with the design recommendations provided by the manufacturers. However, it is unlikely that outlets designed accordingly will give rise to under-performance in practice. The designer should examine the basis of claimed hydraulic capacities and the corresponding outlet spacings.

Manufactured Linear Drainage Channels

7.17 Manufactured linear drainage units have been available in the UK for a number of years and have been used extensively for the drainage of large paved areas, notably car parks. One of the two common types of system is based on a trough or channel made of concrete, polymer concrete, glass reinforced concrete or other similar material. Cast iron and steel systems are also available. Troughs are covered by some form of grating, which will be either integral with the channel or a separate element which is bolted or otherwise fixed to the channel. The other common system comprises concrete blocks, typically 300mm square in section and 600mm to 900mm in length. These are cast with an internal cylindrical cavity such that a continuous pipe is formed when units are laid together. Water is admitted through either a continuous slot or through frequently spaced holes in the top face. Side entry inlets may also be specifically incorporated for use as edge drainage with porous asphalt surfacing.

7.18 Use of linear drainage channel units in the motorway and all-purpose trunk road network will require the approval of the Overseeing Organisation.

Such approvals have generally only been granted for use in nosings and crossover situations and in locations which are unlikely to be trafficked. Restrictions will be placed upon the usage of manufactured units which require the mechanical interlocking of a grating to the trough section of a unit. Some units may also be unsuitable for areas of pedestrian and cyclist usage. Manufactured units have been more extensively used on the Continent than in the UK and it is possible to obtain proprietary products with comprehensive ranges of fittings. Manufacturers will claim hydraulic characteristics and performance of their products. Performance of the units must be compatible with calculated design runoffs from the pavement into the proposed linear drainage systems and the proposed outlets from those systems.

In Situ Concrete Linear Drainage Channels

7.19 This form of construction has been extensively used, primarily by slip forming, on major roads on the Continent. Development and practice in the UK has been more recent, and has only been trialled on limited schemes. These channels comprise formation of a longitudinal cylindrical conduit within an in situ concrete

block approximately square in cross-section. Longitudinal slots formed in the block above the conduit transmit surface-water run-off into the conduit beneath, and the form of these units is thus very similar to one of the manufactured types of channel described earlier. These units are normally constructed by slip forming, the longitudinal conduit being generally formed by inflated plastic tubes which are later removed, or by a PVC pipe which is left in position. The longitudinal slots overlying the conduit are formed by slip-forming.

7.20 Specification in practice is based primarily upon the 1100 Series (MCHW 1) clauses and the Code of Practice 'BS5931. Machine laid in situ edge details for paved areas' (ref 3). It is necessary that the construction be structurally adequate, and the slip formed channels generally incorporate longitudinal reinforcement.

7.21 There are considerable differences in the tolerances and quality control that can be achieved with in situ construction relative to pre-cast. In the meantime, in situations where a linear drainage slot-type channel is desired, the Overseeing Organisation would be able to provide guidance on current best-practice. It is possible that this form of construction will be well suited for installation alongside slip formed vertical concrete barriers (VCBs) as construction of these becomes more common.

Combined Channel and Pipe Systems

7.22 Guidance on the hydraulic and structural design of combined channel and pipe systems is given in HA 113 (DMRB 4.2). They comprise surface water channels with an internal pipe formed within the base of the units that is able to carry additional flow. The systems are particularly well suited to in situ construction in concrete using slip forming techniques, although they can also be constructed using other methods. Use of such systems can remove the need for a separate carrier drain in the verge and can enable flow to be carried longer distances between outlets. If no carrier drain is required, more space can be made available in the verge for other services.

Pipe Design

Hydraulic

7.23 Hydraulic design of a pipe network is generally accomplished by computer application of the principles described earlier in this Chapter. Cross-carriageway pipes, which discharge flows from the central reserve to the verge and thence to outlet, should have sufficient spare capacity to ensure that storms in excess of the design storm will not cause surcharges of the central reserve drainage. Cross connections should be adequately sized to avoid this. Considerations of provision of some spare capacity are relevant to all outlet pipes, which, in surcharge conditions, may otherwise jeopardise the safety of the highway.

7.24 Following research in to sediment volumes generated by high speed roads and the introduction of pollution reducing sumpless gullies there is a need to design the piped drainage to transport sediment and hence reduce maintenance. Guidance on the design of pipelines for reduced sediment deposition is contained in HA219 (DMRB 4.2)

Structural

7.25 Guidance on the structural design of pipes is set out in two publications:

i) A Guide to Design Loadings for Buried Rigid Pipes (ref. 5); and

ii) Simplified Tables of External Loads on Buried Pipelines (ref. 10).

7.26 Guidance on permissible combinations of pipe and bedding materials applicable to MCHW is set out in HA 40 (DMRB 4.2). This document guides the selection of pipes in trenches with cover depths between 0.6m

and 6.0m and with diameters from 100 to 900mm in carrier drains and from 100 to 700mm in filter drains. Pipe materials covered within the document include rigid pipes of vitrified clay and precast concrete and flexible pipes of uPVC, polyethylene and polypropylene. MCHW 2 guides upon necessary specifications for plastics pipes, and also upon exclusions or special treatments necessary to withstand chemical attack because of groundwater conditions.

7.27 Analysis of pipes outside of this range will require recourse to other guidance documents, but this should not generally be necessary at design stage. Where it is necessary to lay pipes beneath carriageways with very shallow depths of cover the characteristics of ductile iron pipes should be borne in mind. These are semi-flexible and able to withstand high loadings, not just in the permanent situation, but also during construction. Guidance on structural strength and loadings can be obtained from manufacturers. A useful publication guiding upon characteristics and design of a broad range of pertinent drainage materials is the "Materials Selection Manual for Sewers, Pumping Mains and Manholes" published in January 1993 by the Foundation for Water Research (ref. 6).

Discharges to Outfalls and Soakaways

7.28 MCHW 1 Clause 509 requires that, unless otherwise specified in Appendix 90/1, carrier, foul and filter drains (but excluding fin and narrow filters drains) shall be surveyed by either Closed Circuit Television (CCTV) or using the alternative methods outlined in IAN 147.

7.29 A balance needs to be struck when considering whether highway runoff should be discharged to surface waters or to ground. In some cases the effect on receiving surface waters could be such that discharge to ground may be appropriate. This could apply where the discharge would aggravate an existing flooding risk, or where it could have a potentially disproportionate effect on pollution within the receiving waters. Advice on the design of outfalls and culverts is given in HA 107 (DMRB 4.2).

7.30 Advice on the design and construction of soakaways is given in HA 118 (DMRB 4.2). A number of factors must be evaluated in their design:

soakaways must not allow direct discharge to groundwater, for example via boreholes;

soakaways must not be sited within 5m of a building;

soakaways must not lead to a risk of instability, either by washing out of fines, or of saturation of road foundations due to inadequate capacity;

soakaways must not increase the risk of groundwater flooding.

7.31 Designers must ensure there is adequate, safe access to soakaways for maintenance for both operatives and plant. Provision must be made for all maintenance operations to be carried out without disruption to traffic.

8. CONTROL OF POLLUTION AND FLOODING

General

8.1 Whilst the primary aims of highway drainage systems are to provide rapid removal of surface water from the road surface and to provide effective sub-surface drainage, it is important that drainage systems do not increase flood risk to downstream receptors, and do not cause pollution to receiving watercourses and environments. Therefore highway drainage systems should contain measures to control the risk of downstream pollution or flooding. Broadly, measures to control flooding are likely to include limiting (attenuating) peak outflows and providing an appropriate volume of water storage in the system to accommodate large or critical storm events. Measures to control pollution need to operate in all conditions and will need to be designed to be effective for all storm events and not just the "critical storm" for which drainage and attenuation systems are traditionally sized.

8.2 HD 49 (DMRB 4.2.1) and HD 45 (DMRB 11.3.10) set out the legislative framework in which water resources are managed and the responsibility of the Highway Authority to ensure that highway discharges comply with pollution legislation. Along with HAWRAT (Highways Agency Water Risk Assessment Tool) it also provides a sound method for assessing the environmental risks posed by the discharge of highway runoff. HAWRAT goes as far as indicating the level of treatment required (if any) to reduce the risk to an acceptable level. Tables 8.1 and 8.2 provide further information on the different types of treatment measures, their efficiencies for removing common highway pollutants and their compatibility. Appropriate maintenance of these systems in accordance with the procedures stated in the relevant management and maintenance contract should minimise the risk of a polluting or flooding incident occurring on the Network.

8.3 Systems with the potential for control of pollution or flooding include:

- **Spillage control:** Sediment Tanks, Vortex Separators, Oil Separators, Lined Ditches, Penstocks, Baffles, Kerbs and Gullies, Surface Water Channels, Combine Surface and Sub-surface Drains;
- **Other pollution control:** Unlined Ditches, Oil Separators, Sediment Tanks, Filter Drains;
- **Flow control:** Combine Surface and Sub-surface Drains, Carrier drains (oversize), Ditches, Combined Kerb and Drainage, Reservoir Pavements;
- **Vegetated systems:** Dry Ponds/Detention Basins, Wet Ponds/Retention Basins, Infiltration basins and soakaways, Wetlands, Grassed channels, Swales.

8.4 Where risks of potential pollution or flooding have been identified and the need for controls identified, the use of vegetated drainage systems should be considered in the first instance. Guidance on these systems is given below and in HA 103 (DMRB 4.2). Guidance on grassed surface water channels for highway runoff is given in HA 119 (DMRB 4.2). There may be situations where limited space restricts the use of vegetated systems and in these cases, the use of conventional drainage systems, either independently or in combination with vegetated systems should be considered. Designers should ensure that systems such as oil separators and lagoons, that may be remote from the highway, are provided with safe means of access for maintenance.

8.5 Treatment efficiencies of various components in reducing pollution in routine runoff are illustrated in Table 8.1, which has been prepared following a literature review of the current state of knowledge for the efficacy of a range of treatment systems for highway runoff. These figures are presented as a guide. The effectiveness of the various components in reducing the impact of a serious polluting spillage, risk reduction factor, is illustrated in Table 8.2: Spillages – Indicative Pollution Risk Reduction Factors.

Flood Risk

8.6 Flood risks to a highway should be assessed at the planning stage, in accordance with HD 45 (DMRB 11.3.10).

8.7 Consultation will usually be required with the relevant Environment Protection Agency and Overseeing Organisation regarding appropriate runoff rates.

8.8 Peak discharge rates must be controlled and appropriate attenuation storage provided within the system for a 1 in 100 year return period.

8.9 The drainage system as a whole must be assessed for the consequences of exceedence for return periods in excess of 1 in 100 years. Where the consequences of any identified flooding are unacceptable, the Overseeing Organisation must be consulted.

Control of Pollution

8.10 Significant pollutants that are routinely found in UK road runoff and which pose a risk of short-term acute impacts (from dissolved/soluble pollutants) and/or long-term chronic impacts (from sediment-bound pollutants) on ecosystems are presented in HD 45 (DMRB 11.3.10).

8.11 Appropriate treatment components will need to be chosen depending on the expected highway pollutants of the scheme in question. Unlike hydraulic design, which focuses on providing system capacity for the largest or "critical" storm duration for a given return period, treatment systems should be designed to treat the majority of the storm events occurring over a given year and not solely designed for the largest critical storm. A degree of bypass may be acceptable for the larger storm events, where runoff volumes will be higher and therefore there will be a greater degree of dilution.

8.12 The treatment system components described in this chapter are intended to be the starting point for the design process and not an exhaustive list. Table 8.1 presents the potential treatment efficiencies for the various measures for different types of contaminants, and Figure 8.1 provides guidance on the selection process.

Treatment System Type	Suspended Solids (% removal)	Dissolved Copper (% removal)	Dissolved Zinc (% removal)
Swales and Grassed Channels[a]	80	50	50
Infiltration Basins/Soakaways	See note b	See note b	See note b
Dry/Detention Ponds[a]	50	0	0
Wet/Retention Ponds	60	40	30
Wetlands (Surface Flow)	60	30	50
Vortex Grit Separators	40	0[c]	15
Sediment Tanks	40	0[c]	0[c]
Oil Separators	0[d]	0[d]	0[d]
Reservoir Pavements/Porous Asphalt	50	0	0
Vegetated Filter Strips[a]	25	15	15
Combined Surface and Sub-surface Drains/Filter Drains[a]	60	0	45
Ditches[a]	25	15	15

a. If the treatment system is designed with an element of infiltration, the risk to groundwater should be evaluated using Method C in HD 45.
b. The effluent from infiltration systems cannot be measured in the same way as systems which discharge to surface waterbodies. While the risk to groundwater from well-designed infiltration systems is generally low, a groundwater risk assessment should be carried out using Method C in HD 45.
c. Variable and negative values recorded for dissolved copper and zinc – therefore not considered reliable by the Overseeing Organisation for removal of dissolved metals.
d. Oil separators can only be chosen for treating oils and must not be relied upon to treat suspended solids, or dissolved metals.

Table 8.1: Indicative Treatment Efficiencies of Drainage Systems

System	Optimum Risk Reduction Factor R_F (%)
Passive Systems	
Filter Drain, Combined surface and sub-surface drain	0.6 (40%)
Grassed Ditch/Swale	0.6 (40%)
Pond	0.5 (50%)
Wetland	0.5 (50%)
Infiltration basin	0.6 (40%)
Sediment Trap	0.6 (40%)
Vegetated Ditch	0.7 (30%)
Active Systems	
Penstock/valve	0.4 (60%)
Notched Weir	0.6 (40%)
Other Systems	
Oil Separator	0.5 (50%)

Note: These factors and corresponding percentage reductions represent what is considered achievable. In many situations a higher factor, representing a lower risk reduction, may be more appropriate. For example, a short length of filter or combined surface water and groundwater drain may only reduce a spillage risk by 20%, so a factor of 0.8 should be used.

Table 8.2: Spillages – Indicative Pollution Risk Reduction Factors

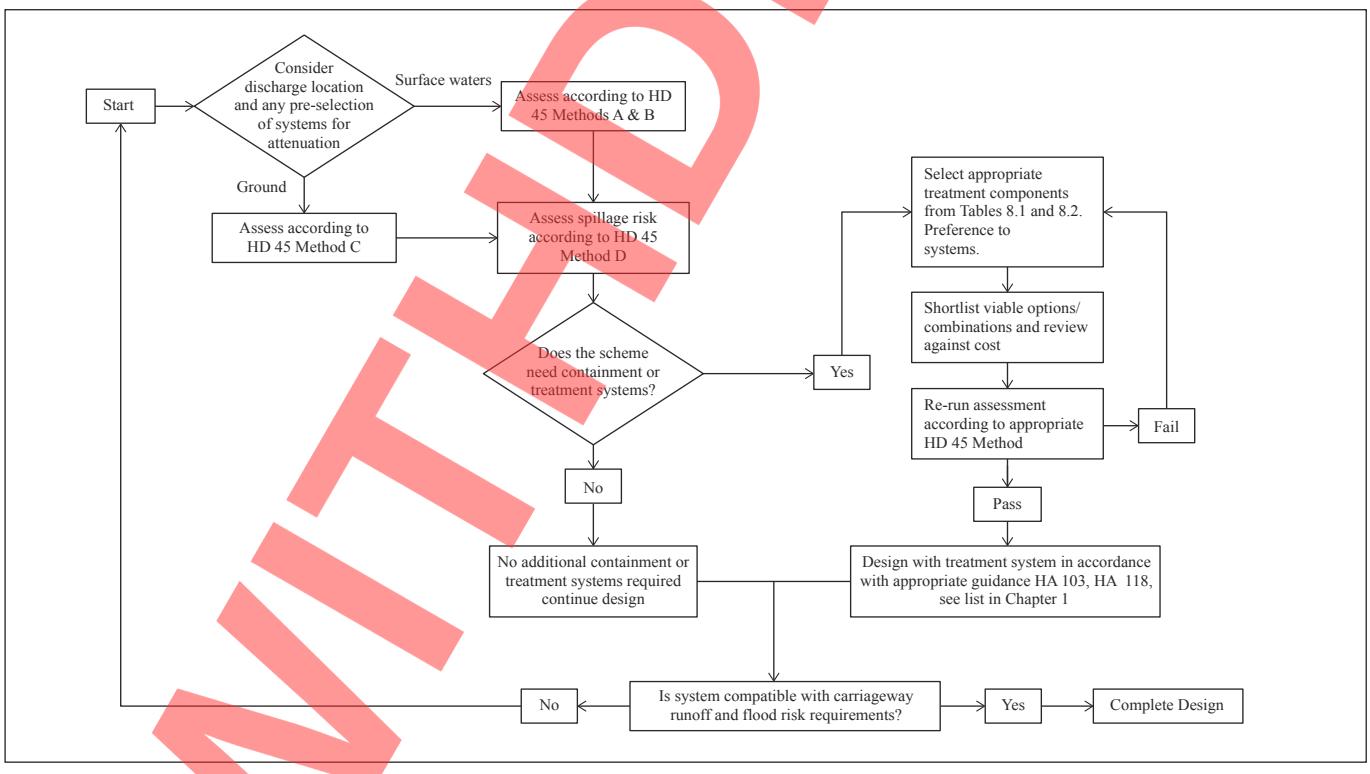

Figure 8.1: Recommended Selection of Treatment Systems

Other Drainage Components

8.13 Whilst the treatment components described in Table 8.1 are likely to be the preferred methods for providing treatment of highway runoff, the following components also continue to have a role to play, if not considered as treatment components in their own right.

Kerbs and Gullies

8.14 Gully pots can have both beneficial and negative impacts on water quality for receiving watercourses. The main benefit from gully pots is their ability to capture potentially contaminated sediments during normal rainfall events prior to discharge into a receiving watercourse. They are more effective at trapping the coarse sediments than the finer ones. They can also provide a good first line of defence in the event of an accidental spillage.

8.15 However, high inflow rates can cause re-suspension of sediments within the gully pot and subsequent discharge of the liquor from the gully pot can result in a pollutant flush into the receiving drainage network or watercourse. It has been found that turbulence in the sump causes mixing of any trapped oils with the water being discharged. The best way of avoiding such re-suspension or mixing of oils is to ensure that the gradient of the pipe leading to the gully is as shallow as possible, consistent with adequate hydraulic performance. Where this cannot be achieved, sumpless gullies should be considered. HA 105 (DMRB 4.2) provides specific advice on this type of gully.

Surface Water Channels and Drainage Channel Blocks

8.16 In situations where channels are not self-cleansing, deposition of gross pollutants and sediments is likely to occur. Increased sediment build-up potentially poses a safety threat to the travelling public, due to runoff ponding behind deposited materials. To avoid this, gradients of long lengths of these channels should be designed to ensure that they are self-cleansing, with sediments being deposited in a downstream system. Channels can be designed to allow for pollution control by emergency response kits, such as those used by Environment Agency personnel. These can be rapidly deployed to form a watertight seal at gully gratings, preventing discharge of runoff to the drainage network.

Combined Kerb and Drainage Blocks

8.17 Combined kerb and drainage systems can attenuate flow, mainly due to the high storage capacity of the design. Where attenuation storage or balancing ponds are proposed as part of the design, the use of combined kerb and drainage systems can potentially contribute storage volume to help to reduce the size of the primary attenuation components.

Piped Systems

8.18 In the event of accidental spillage, piped systems can provide a form of spillage containment if adequate downstream control is provided. This could take the form of a penstock, handstop, or an orifice that can be readily blocked in emergency.

Ditches

8.19 Unlined ditches have some potential to control pollution, due to infiltration of the runoff through the soil profile (ref 13) and any vegetation present. Ditches with gentle side slopes can be considered to have similar properties to swales, which are described in HA 103 (DMRB 4.2). Ditches are in common use on the UK's motorway and all-purpose trunk road network, however information on their treatment performance is sparse. This may be because their primary function is hydraulic and not for treating runoff. Nevertheless,

ditches may present a degree of treatment potential when residence times are long, infiltration can occur and vegetation is present. Ditches with concrete or similar facing will not have the same potential, but can be adapted to contain spillages. A lined ditch can act as a containment basin if located between the road drain and the receiving watercourse. It should have a minimum of 25m^3 capacity and have a downstream control that can be shut or blocked in the event of accidental spillage of pollutants on the road. Where ditches are located above permeable strata, there is a risk that highway runoff will infiltrate and contaminate any underlying aquifer. This can be prevented by facing the ditch with concrete/impermeable liner or placing the impermeable liner beneath it.

Informal Drainage (Over the Edge)

8.20 Informal drainage, sometimes referred to as over-the-edge drainage, can provide, in some circumstances, some degree of pollution control as highway runoff is allowed to filter through vegetation on the slope. Field studies of vegetated filer strips/embankments have shown the pollutant retention was primarily a surficial phenomenon, limited to the top 50cm of highway embankment soils. As with ditches, however, there is the risk of infiltration and contamination of groundwater. In such locations the toe ditch should be lined to prevent such pollution. Pollution control is also possible with this drainage system using a downstream control.

Combined Surface and Sub-surface Drains

8.21 Combined surface and sub-surface drains offer some protection against release to receiving water of accidental spillages, as they can delay the release of pollutants. However, once polluted effluent has entered the carrier pipe, pollution control is very limited without downstream controls such as penstocks. The filter media can also adsorb suspended solid pollutants and heavy hydrocarbons, reducing downstream pollution risk from routine runoff. In locations where the routine runoff causes a build-up of pollutant in the filter media, it may be necessary to clean or recycle the filter material every ten years to ensure it remains sufficiently permeable; guidance is contained in HA 217 (DMRB 4.2). This, or replacement, will probably be needed if contaminated by a serious accidental spillage.

8.22 The use of combined surface and sub-surface drains should always be assessed in conjunction with the risk to groundwater pollution. Impermeable trench liners may be appropriate where groundwater pollution risks are high.

Sediment/Oil Separators

8.23 There are two main types of oil separator: the full retention separator and the bypass separator. Their primary function is to remove oil from the water column, but they are less effective at removing soluble oils or other water-soluble liquids.

8.24 Full retention separators are used where all the runoff has to be treated. Their application will be very rare on highways, and their use is usually reserved for locations such as garage forecourts. Exceptionally, they may be used in maintenance depots or construction sites, and where the receiving environment is especially sensitive.

8.25 Bypass oil separators are designed to capture and control flows from rainfall events of up to 5mm/hour, which is about 10% of the typical peak rainfall intensity in the UK. They rely on the greatest pollutant load being carried by the “first flush” of a runoff event. Only 1% of all rainfall events in the UK have a rainfall intensity exceeding 5mm/hour, so such interceptors will cater for the large majority of events.

8.26 On rural highways, oil separators may not be the optimum solution, due to their requirement for frequent maintenance. Consideration must be given to installing a vegetated drainage system, as described in HA 103 (DMRB 4.2), or to a less expensive containment facility.

8.27 Sediment tanks capture silts, coarse sediments and particulates. The efficiency of removal depends on a number of factors including inflow velocity, separator size, retention time, maintenance frequency and the inherent settlement time of individual particles given their size and charge. Separators operate by varying mechanisms, including extended retention times, baffled chambers, weirs, hydraulically separated chambers, multiple chambers and centrifugal or centripetal force (vortex or hydrodynamic separators) (ref 13).

8.28 Published studies suggest that the average suspended solids removal efficiency of sediment tanks to be around 40%. This is not particularly high in comparison with other treatment systems although without this form of primary treatment the function of other systems could be compromised. Ideally, drainage systems should be designed to trap sediment in areas/separators from where it can be easily removed – thereby avoiding expensive and habitat-disruptive maintenance to ponds and wetlands.

8.29 For metals, dissolved and total, separators show a variable ability to retain them; however this is not their primary design function. Re-entrainment of heavier PAHs has been observed in full retention oil separators, most likely caused by turbulence and re-mixing from steep gradients on incoming pipes. Therefore these should be kept to reasonable gradients to minimise this effect.

Other Containment Facilities

Sediment Lagoons and Tanks

8.30 These structures should be constructed above flood plain level, if they are required to provide storm water control. Aquatic growth in lagoons will act as a filtering mechanism for suspended particles and pollutants. Incorporation of by-pass facilities may be possible such that only the first flush runoff is given full settlement, subject to consultation with the regulatory authority. For more advice on the design and selection of settlement lagoons see HA 103 (DMRB 4.2).

Pollution Control Devices

Penstocks

8.31 Penstocks comprise a flat plate, fitted to a pair of guide slots on a headwall or chamber wall, which is raised and lowered using a screw thread operated by a wheel. During routine highway operation, penstocks should be in the fully raised position, and have no influence on flow passing through the drainage system. The primary function of penstocks is to control spillage incidents. If lowered in time prior to discharge of significant quantities, penstocks can potentially retain 100% of spilled material, which are then relatively easily removed by suction or other methods, depending on the material involved. Operation of penstocks should only be by either emergency or EPA personnel, or highway maintenance contractors. Designers must ensure that such devices can be readily located and that they are provided with safe and easy means of access (see Chapter 8).

8.32 If the penstock is lowered over the pipe opening for any other reason, potentially due to vandalism, failure of the screw thread or plate, or not being raised after an incident, the penstock will retain storm water flow, which is likely to result in flooding, or scouring following a breach of the headwall or ditch. Regular inspection and maintenance will be required to ensure they do not become inoperable through long periods without use and to check they are not being vandalized.

Handstops

8.33 Handstops are similar to penstocks except the plate is raised and lowered directly, not using a screw thread. The design should ensure that their use will not be compromised by the need to lift the plate manually. They will generally be cheaper than penstocks, but not as suitable for locations requiring a larger system. As with penstocks, regular inspections and maintenance will be required.

Weirs, baffles

8.34 Weirs and baffles can act as both pollution and flood control devices. Where they are required to reduce spillage pollution risk, they should be designed with a notch or orifice that can readily be blocked by a sandbag in an emergency. Weirs can act as a flow control device by allowing excess flows to overtop the weirs. These flows can then be channelled to attenuation ponds or other flood storage systems.

8.35 Baffles can be placed in open channels or ditches to slow down the flows, and therefore attenuate the discharge. Like weirs, they can be adapted to allow them to be blocked in emergency, thus retaining accidental spillages. Where baffles are used for spillage control, there should always be at least 25m^3 of containment.

Hanging Walls

8.36 Hanging walls comprise simple baffles constructed across open ditches, so that oils and other non-miscible pollutants are retained. The ditch will have a reduced invert level downstream, so that the flow is siphoned beneath the baffle. Careful attention will need to be given to the location, ditch gradient and potential storage capacity of the system. Access for emergency or maintenance personnel will be required.

Flow Control Devices

8.37 Where attenuation of a flow is required, a device such as a vortex chamber can be installed downstream of a pond, ditch, drain or other storage facility, which will have to be designed with adequate storage capacity. These flow control devices should be designed for the specific job they are required to perform. Manufacturers are usually able to provide design details. For some locations, an orifice plate will suffice.

Reservoir Pavements

8.38 Full depth reservoir pavements allow surface water to infiltrate into the subgrade, either partially or fully depending on the design, or to be captured for controlled release off site. With proper design and installation, they can provide an economical solution for management of storm water.

8.39 Traffic levels on the UK motorway and all-purpose trunk road network roads require strong pavements and permeable pavements can only be constructed as a departure from standard. There may however be paved areas remote from the running lanes that can be constructed using reservoir pavements.

Conventional Drainage Systems	Potential for Spillage Control	Potential for Pollutant Removal	Potential for Storm Water Control	Compatibility with Vegetated Drainage Systems				
				Grassed Channels (Swales)	Constructed Surface Wetlands	Balancing/ Sedimentation Ponds	Ponds	Hybrid Systems
Distribution Systems					♦	♦	♦	♦
• Kerbs and Gullies	♦							
• Surface Water Channels	♦			♦	♦	♦	♦	♦
• Combined Kerb and Drainage			♦		♦	♦	♦	♦
• Piped systems	♦		♦		♦	♦	♦	♦
• Ditches (Unlined)		♦	♦	♦	♦	♦	♦	♦
• Combined Surface and Sub-surface Drains	♦	♦	♦	♦			♦	♦
• Ditches (Lined)	♦		♦		♦	♦	♦	♦
Separators								
• Oil/Sediment Separators	♦	♦		♦	♦			♦
Pollution Control Devices								
• Penstocks	♦					♦	♦	♦
• Weirs and baffles	♦		♦	♦		♦	♦	♦
Flow Control Devices								
• Flow Regulators			♦		♦		♦	♦
Soakaways		♦		♦	♦	♦	♦	♦

Table 8.2: Runoff Management Capabilities of Conventional Drainage Systems and Compatibility with Vegetated Drainage Systems

9. SIGNING OF POLLUTION CONTROL DEVICES

Introduction

9.1 This chapter gives guidance to the signing of pollution control devices. The sign is intended to enable the emergency services to locate the pollution control device as quickly as possible. It is not a traffic sign within the meaning of section 64 of the Road Traffic Regulation Act 1984 and the Roads Traffic Regulations (Northern Ireland) 1997.

The Design of Pollution Control Device Signs

9.2 The sign must be designed in accordance with BS EN 12899-1 'Fixed, vertical road traffic signs Part 1: Fixed Signs' (ref 4).

9.3 The location of the sign must be within the highway boundary and must be referenced in the drainage database described in Chapter 10.

9.4 The sign should be located at least 600mm from the edge of a single carriageway or at a hardened verge and 1500mm on high-speed dual carriageway or motorway. Locations other than at the edge of the carriageway are subject to approval by the Overseeing Organisation. The mounting height of the sign should be at least 900mm above the highest point of the carriageway and can be increased up to 1500mm where excessive spray is likely to occur around the sign.

9.5 As this sign is regarded as a notice for the emergency services, the sign face is to have a light green background with white legends and a yellow border (see Figure 9.1). The X-height of the sign is to be 50mm.

9.6 Illumination of the sign is not required. However, the sign face shall be made of retro-reflective Class 1 material to BS EN 1463-1:1998 Road marking materials. Retro reflecting road studs. Initial performance requirements.

9.7 The sign should give details of the location of the pollution control device as referenced in the data management system. Chapter 10 gives details of how such systems should be managed.

Maintenance of Pollution Control Device Signs

9.8 The sign must maintain its visibility to be effective.

9.9 It should be checked annually for signs of discolouring or deterioration of the sign face. Inspections of such signs should include inspections carried out after dark and replacement and/or repairs of signs should be initiated if necessary. Further advice is given in TD 25 'Inspection and Maintenance of Traffic Signs on Motorway and All-Purpose Trunk Roads' and the Traffic Signs Manual Chapter 1: Part 9 Maintenance of Signs.

Diagram No. 1.1			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	190mm
Material	CLASS 1	Area	0.06 sq. m

Diagram No. 1.2			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	310mm
Material	CLASS 1	Area	0.10 sq. m

Diagram No. 1.3			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	410mm
Material	CLASS 1	Area	0.13 sq. m

Diagram No. 1.4			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	410mm
Material	CLASS 1	Area	0.13 sq. m

NOTES The sign shall be designed in accordance to BS EN 12899-1:2001

Figure 9.1: Signing of Pollution Control Devices

10. IMPLEMENTATION OF DRAINAGE DATA MANAGEMENT SYSTEM

Introduction

10.1 The Overseeing Organisation provides a Drainage Data Management System, which is a Geographical Information System (GIS) holding all drainage asset inventory and condition data nationally. In addition, the system holds electronic versions of drawings and reports.

10.2 Full information regarding preparation and submission of data for inclusion on the Drainage Data Management System is given in HD 43 (DMRB 4.2) and SD 15 (MCHW 5.9), as modified by IAN 147. On completion of works new and / or updated data are required to be prepared and submitted for addition onto the Drainage Data Management System.

10.3 Records of inventory and condition for all drainage assets within the Overseeing Organisation's responsibility must be uploaded to the Drainage Data Management System. This data must comply as a minimum with the mandatory requirements given in the documents referenced in 10.2.

10.4 In England and Wales, all data to be uploaded to the Drainage Data Management System must be prepared in the appropriate formats described in IAN 147. In Scotland and Northern Ireland users should consult the Overseeing Organisation

As-built information

10.5 Following completion of a construction, maintenance, improvement or renewal scheme, existing drainage data in the Drainage Data Management System may be superseded or incomplete. In addition, as-built drawings and other documents produced as part of the scheme will hold important details, including those that form part of the Health and Safety File, which should be held alongside the drainage asset data.

10.6 The drainage asset inventory and condition data held in the Drainage Data Management System must be updated to incorporate the new or modified drainage system. This must include removing asset records that are now obsolete. The entire drainage catchment must be held within the same dataset. It is not sufficient to add a new dataset to the system containing just the new or modified assets, where there is already existing data.

10.7 As-built drawings must be uploaded to the system. In England and Wales, these must be provided as Drawing Sets, as described in IAN 147.

10.8 Record status reports must be uploaded to the Reports Database in the appropriate indexed PDF format. Instructions for production and submission are available to download from the Drainage Data Management System.

10.9 Signed design certificates must be scanned and uploaded to the relevant record in the Reports Database on the Drainage Data Management System.

10.10 Where a scheme has addressed the flooding or pollution risk associated with any Priority Asset on the Overseeing Organisation's Drainage Data Management System, the entry in the register must be updated.

10.11 Other documents such as photographs, schedules, etc may be uploaded to the Drainage Data Management System and attached to the relevant item in the database. Documents may either be uploaded to individual assets or to the dataset, depending on their applicability.

11. NORMATIVE & INFORMATIVE REFERENCES

Normative References:

1 Manual of Contract Documents for Highway Works (MCHW)

Specification for Highway Works (MCHW 1) –Clauses 509, 601.9 and 601.10

Highway Construction Details (MCHW 3) – Including B13, B and F Series Drawings.

2 Design Manual for Roads and Bridges (DMRB)

BD 30 Backfilled Retaining Walls and Bridge Abutments (DMRB 2.1)

HA 37 Hydraulic Design of Road Edge Surface Water Channels (DMRB 4.2)

HA 39 Edge of Pavement Details (DMRB 4.2)

HA 40 Determination of Pipe and Bedding Combinations for Drainage Works (DMRB 4.2)

HA 44 Design and Preparation of Contract Documents (DMRB 4.1.)

HD 41 Maintenance of Highway Geotechnical Assets (DMRB 4.1)

HD 43 Drainage Data Management System for Highways (DMRB 4.2)

HA 78 Design of Outfalls for Surface Water Channels (DMRB 4.2)

HA 79 Edge of Pavement Details for Porous Asphalt Surface Courses (DMRB 4.2.4)

HA 83 Safety Aspects of Road Edge Drainage Features (DMRB 4.2)

HA 102 Spacing of Road Gullies (DMRB 4.2)

HA 103 Vegetated Drainage Systems for Highway Runoff (DMRB 4.2).

HA 104 Chamber Tops and Gully Tops for Road Drainage and Services: Installation and Maintenance (DMRB 4.2)

HA 105 Sumpless Gullies (DMRB 4.2)

HA 106 Drainage of Runoff from Natural Catchments (DMRB 4.2)

HA 107 Design of Outlet and Culvert Details (DMRB 4.2)

HA 113 Combined Channel and Pipe System for Surface Water Drainage (DMRB 4.2)

HA 118 Design of Soakaways (DMRB 4.2.)

HA 119 Grassed Surface Water Channels for Highway Runoff (DMRB 4.2.)

HA 217 Alternative Filter Media and Surface Stabilisation Techniques for Combined Surface Water and Ground Water Drains (DMRB 4.2)

HA 219 Determination of Pipe Roughness and Assessment of Sediment Deposition to Aid Pipeline Design (DMRB 4.2)

HD 45 Road Drainage and the Water Environment (DMRB 11.3.10)

HD 25 Foundations (DMRB 7.2)

HD 26 Pavement Design (DMRB 7.2)

HD 27 Pavement Construction Methods (DMRB 7.2)

HD 43 Drainage Data Management Systems for Highways (DMRB 4.2)

HD 49 Drainage Design Policy Principal Requirements (DMRB 4.2.1)

HD 50 The Certification of Drainage Design (DMRB 4.2.1).

TA 57 Roadside Features (DMRB 6.3)

TA 80 Surface Drainage of Wide Carriageways (DMRB 4.2)

TD 9 Highway Link Design (DMRB 6.1)

TD 16 Geometric Design of Roundabouts (DMRB 6.2)

TD 25 Inspection and Maintenance of Traffic Signs on Motorway and All-Purpose Trunk Roads (DMRB 8.2)

IAN 147 Drainage Surveys and Data

3 BS 5931: 1980 'Machine laid in situ edge details for paved areas'

4 BS EN 12899-1:2007 'Fixed, vertical road traffic signs Part 1: Fixed Signs'

Informative References:

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