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Transport Infrastructure Ireland

TII Publications

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Drainage Systems for National Roads

DN-DNG-03022

February 2024

DN Design

Standards

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TII Publications

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Contents

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Drainage Systems for National Roads DN-DNG-03022

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Amendment Details:

Clause 1.4 Implementation is amended.

Date: February 2024

Page No: 1, 18, 28

Section No: 1.3, 4.5, 4.6, 6.11

Amendment Details:

TII Template updated from the previous NRA template.

References to historical NRA documents updated to refer to current applicable TII Publications.

Section 1.3 Implementation of Standard updated.

Section 4.5 – additional paragraph added in respect of verge space requirements where separate drainage systems are used.

Section 4.6 Reference to UK HA 217 removed from Clause 4.6 (previously Clause 4.13 in June 2015 version).

Section 6.11 updated to specify that a minimum cover diameter of 750mm is required where chamber depths exceed 2m.

Contents

1. Introduction

1.1 General

This Standard gives guidance on the selection of the types of surface and sub-surface drainage for National Roads projects. It describes the various solutions that are available to drain national roads in Ireland, including their potential to control pollution and flooding. It also includes guidance on drainage of earthworks associated with roads.

The 2015 revision of the TII's drainage standards was precipitated by post-doctoral research carried out under the TII's Research Fellowship Programme and mentored by the TII's Environment Unit. This research looked at the impacts of national road drainage systems on both surface and ground water. The research concluded that the TII's drainage standards needed to be expanded to promote the use of sustainable drainage systems and to maximise environmental benefits. A report entitled *Drainage Design for National Road Schemes – Sustainable Drainage Options* (TII, 2014) documents this research and provides useful background reading to the TII's drainage standards. This document is available on the TII Publications website (www.tiipublications.ie).

1.2 Scope

The guidance given on drainage design is applicable to all National Roads projects. It provides a summary of design documents available, primarily those published on behalf of Transport Infrastructure Ireland. It describes the various alternative solutions that are available to drain national roads in Ireland, including their potential to control pollution and flooding. It advises upon selection in principle, and gives guidance on the detailed design of the various pavement edge drainage alternatives with regard to available design guides.

1.3 Implementation

This Standard shall be used for the design of all new or improved National Roads including motorways unless otherwise agreed with Transport Infrastructure Ireland (TII). All roads affected by National Roads projects shall also be designed in accordance with this Standard unless otherwise agreed with the relevant Road Authority. The design of Local and Regional Roads which are constructed or improved as part of a National Road Scheme shall be designed in accordance with this Standard.

1.4 Design Principles

There are three major objectives in the drainage of national roads:

a) the speedy removal of surface water to provide safety;
b) provision of effective sub-surface drainage to maximise longevity of the pavement and its associated earthworks; and
c) minimisation of the impact of the runoff on the receiving environment.

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

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. Road 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.

The necessary objectives can be achieved by:

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

b) separate systems, where the sub-surface water is drained through a separate system from the one which is used for collection of surface water. Sub-surface water of a separate system will be collected in a filter drain, fin or narrow filter drain or conveyed and discharged through an extended capping layer.

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

Drainage networks incorporating systems such as sediment traps, filter drains, grass channels, wetlands, retention ponds, other vegetated systems and oil/sediment separators 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 road runoff are:

a) sedimentation – the removal of suspended solids;

b) separation – the removal of all solids and non-aqueous liquids;

c) 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. Guidance on the assessment of the risk of either pollution or flooding is given in TII DN-DNG-03065 Road Drainage and the Water Environment and the TII Environmental Assessment and Construction Guidelines. Chapter 7 of this Standard gives examples of conventional drainage systems that have the potential to mitigate the effects of runoff. Guidance on vegetated drainage systems is given in TII DN-DNG-03063 Vegetated Drainage Systems for Road Runoff. Guidance on the design of soakaways is given in TII DN-DNG-03072 Design of Soakaways and on the design of grassed surface water channels in TII DN-DNG-03073 Grassed Surface Water Channels for Road Runoff.

Drainage designs shall ensure that:

a) all drainage systems are accessible for inspection and maintenance;

b) all impermeable and semi-impermeable surfaces are adequately drained;

c) drainage systems do not have an adverse impact on existing ecology, surface-water hydrology or groundwater hydrogeology;

d) in the interest of pollution control and containment the road drainage shall, wherever possible, be kept separate from other catchment drainage; and

e) the road drainage causes no disruption in water supply to landowners/occupiers who obtain their water from wells, boreholes, and the like.

In exceptional situations, Transport Infrastructure Ireland may be prepared to agree to a Departure from Standards where the standard is not realistically achievable. Design Organisations faced by such situations and wishing to consider pursuing this course shall discuss any such option at an early stage in design with Transport Infrastructure Ireland.

Proposals to adopt Departures from Standard must be submitted by the Design Organisation to Transport Infrastructure Ireland and formal approval received BEFORE incorporation into a design layout.

2. Effect of Road Geometry on Drainage

2.1 Introduction

Road surfacing materials are traditionally designed to be effectively impermeable, and only a small amount of rainwater should percolate into the pavement layers. It is important that any such water is 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.

2.2 Road Geometry

Drainage is a basic consideration in the establishment of road geometry and vertical alignments should 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 minimum height of embankments above watercourses. They could also influence the depth of cuttings as it is essential that sag curves located in cuttings do not result in low spots which cannot be drained.

TII DN-GEO-03031 Rural Road Link Design and TII DN-GEO-03060 Geometric Design of Junctions contain guidance to minimise problems and dangers in shedding water from carriageways. 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.

TII DN-GEO-03031 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 flat it is better to avoid rollovers completely 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 groundwater drains or some other form of linear drainage collector. Areas of superelevation change require careful consideration. 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. TII DN-GEO-03031 suggests a minimum longitudinal gradient in these cases. This is the net longitudinal gradient including 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 resultant gradient as per the requirements of TII DN-GEO-03031 may require steep design line gradients. 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. It is essential that a coordinated analysis of the horizontal and vertical alignments with reference to surface water drainage is carried out before alignments are fixed. It should also be borne in mind that permissible standards adopted in design may not be achieved in practice as a consequence of the construction tolerances permissible for road levels. Further guidance can be found in TII DN-GEO-03031.

TII DN-GEO-03060 provides guidance 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. Careful consideration should be given to road profiling and the net gradients which result from combination of crossfall and longfall. These may be best indicated by contoured drawings of the required carriageway surface.

2.3 Safety Considerations

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. Detailed guidance is given in TII DN-STY-03069 Safety Aspect of Road Drainage Features and TII DN-REQ-03034 The Design of Road Restraint Systems.

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 hazards as far as possible.

The Designer must also give appropriate consideration to the safety of motorcyclists and non-motorised road users.

2.4 Channel Flow Widths

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.

Gully spacing shall be designed in accordance with TII DN-DNG-03067 Spacing of Road Gullies to meet the flow width criteria stated below.

A basic criterion in all these studies is the width of channel flow adjacent to a kerb which is deemed to be permissible. The maximum permissible flow width (in a 1 in 5 year storm) shall be as follows:

a) **The hard shoulder/hard strip width minus 0.5 metres** for roads with hard shoulder/hard strip widths of 1 metre or greater; or

b) **0.5 metres width** for roads with no hard shoulders/hard strips or hard shoulder/hard strips widths of less than 1 metre or urban situations where pedestrians or cyclists are present.

Double gullies shall be provided at sag points. At approaches to sag points the longitudinal grade may result in uneconomical spacing of gullies and therefore consideration should be given to combined kerb and drainage systems and linear drainage channels where allowable in accordance with Figure 3.1 and Figure 3.2 of this Standard.

Rainfall data should be obtained directly from Met Éireann in the first instance however 2minM5 values required in TII DN-DNG-03068 Hydraulic Design of Road Edge Surface Water Channels, TII DN-DNG-03067 and TII DN-DNG-03073 are not available from Met Éireann and therefore M5-2D, M5-60 and r values required to derive 2minM5 values shall be estimated from maps included in the Flood Studies Report, (NERC, 1975).

The same flow width criterion for kerbed scenarios shall apply to the design of surface water channels under surcharged conditions (1 in 5 year storm). In addition, the design of surface water channels shall contain the flow within the surface water channel for a 1 in 1 year storm. Further guidance is provided in TII DN-DNG-03068 and TII DN-DNG-03073.

Surface water channels can be hard lined or grassed and are formed as an extension to the basic pavement width of a road, and comprise of varying profile sections, usually either dished, triangular or trapezoidal 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. 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, are recognised and dealt with in TII DN-DNG-03062 Edge of Pavement Details.

2.5 Surface Drainage of Wide Carriageways and at Merges and Diverges

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.

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

It is essential that such drainage installations must be safe and structurally adequate to allow for not just errant vehicles but also usage which may occur during motorway lane closures and the trafficking of hard shoulders. Particular care must be taken in respect of abnormal load routes.

2.6 Position of Drainage in Central Reserve and Near Side Hard Shoulders/Hard Strip.

In the central reserve, all drainage features (grassed and concrete surface water channels, linear drainage channels, gullies and combined filter drains) shall be offset a minimum of 500mm from the traffic lane. Drainage channels shall not encroach into the near side hard shoulder/hard strip.

3. Surface Water Collection: Edge Drainage Details

3.1 Introduction

Surface water runoff from the edges of National Roads projects is generally discharged over-the-edge, collected by kerbs and gullies, combined kerb and drainage blocks, surface water channels and channel blocks or by direct runoff into combined surface water and groundwater filter drains adjacent to the pavement edge.

TII Publications deal in some detail with kerbs and gullies, surface water channels, both concrete and grassed, channel blocks, linear drainage channels, combined kerb and drainage blocks and combined surface water and ground water drains. 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 3.1 and a list of documents giving further guidance is set out in Table 3.2. Permissible design options are defined in Figure 3.1 & Figure 3.2. These Figures impose mandatory requirements, and the use of alternative drainage systems will require a Departure from Standards. Guidance upon their application is set out in TII DN-DNG-03068, TII DN-DNG-03062, TII DN-DNG-03067, TII DN-DNG-03073.

The location and design of outfalls for road drainage are important considerations. Guidance on the design of outfalls and culverts is given in TII DN-DNG-03071 Design of Outfall and Culvert Details and guidance on soakaway design can be found in TII DN-DNG-03072 Design of Soakaways. Considerations of detention storage and specific pollution control measures may influence selection of drainage solutions and are described later in this Standard. Guidance on vegetated drainage systems is given in TII DN-DNG-03063 Vegetated Drainage Systems for Road Runoff.

3.2 Kerbs and Gullies

Road surface drainage by kerbs and gullies is commonly used in Ireland. Refer to Figure 3.1 for suitable application of kerb and gully systems on National Roads projects in Ireland. 'Gullies and Pipe Junctions' requirements are set out in Series 500 of TII Specification for Works (TII SPW). Gully connection pipes discharge to outfall generally via 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.

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 road. 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. Operation 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 Chapter 2.

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. Series 500 of TII Standard Construction Details (TII SCD) illustrates permissible alternative types of gullies that provide for varying degrees of entrapment of detritus.

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.

Cuttings with high ground water flows 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 filter drains. Where gullies are required, connections should be made directly into junction pipes in accordance with Series 500 of TII SPW. Pipe types permitted for the carrier drains must be able to accommodate this requirement.

3.3 Surface Water Channels

Surface water channels are normally of triangular or trapezoidal concrete section, usually slip-formed, set at the edge of the hard strip or hard shoulder and flush with the road surface. They are illustrated in Series 100 and 500 of TII SCD and referenced in Series 500 of TII SPW. Their usage is described in TII DN-DNG-03062.

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 economical to design surface water channels such that outlet spacings in the verges are coincident with cross-carriageway discharges from the central reserve.

It is reasonable to assume that the relative risk to vehicles and occupants from impingement on surface water channels is 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.

3.4 Drainage Channel Blocks

Drainage Channel Blocks are generally smaller concrete channel sections of which six shapes of channel block are detailed in Series 500 of TII SCD and referenced in Series 500 of TII SPW. Channel Blocks Type A and B depict a small half-round profile, Type C, a shallow trapezoidal section and Type D, E, F depict interlocking rectangular sectioned units. They 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 road.

There are potential maintenance difficulties associated with the use of drainage channel blocks and the designers will need to give consideration to these factors:

a) any settlement of adjacent unpaved surfaces would reduce their effectiveness.

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

c) 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, pedestrians or other vulnerable users.

3.5 Combined Kerb and Drainage Blocks

Combined Kerb and Drainage Blocks comprise a wide precast kerb unit within which is a hydraulic conduit.

The system is placed adjacent to the pavement which is to be drained. Preformed openings within the kerb face allow surface water to enter the conduit. Water is discharged along the conduit to suitable outlet points. These units and their interface with the road edge are detailed in Series 100 of TII SCD and referenced in Series 500 of TII SPW. Guidance on their use is also set out in TII DN-DNG-03062. Design requirements shall be set out by the designer in numbered Appendices 1/11 and 5/5 to the TII Guidance on Specification for Works (TII GSW). This can be best achieved by consideration of available proprietary precast units. The completed appendices should permit usage from as wide a range as possible of acceptable alternatives.

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.

3.6 Linear Drainage Channels

These are included in Series 500 of TII SPW and 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. When used on shallow gradients they may be prone to maintenance difficulties as described in section 3.4. Refer to Figure 3.1 and Figure 3.2 for suitable application of linear drainage channels on National Roads projects in Ireland.

3.7 Over-the-Edge Drainage

This method of drainage, applicable to embankment conditions, is illustrated in Series 100 of TII SCD, and its usage is described in TII DN-DNG-03062. It is inappropriate for usage in locations where footways or segregated cycleways abut carriageways or on structures. Uncontrolled growth on verges can inhibit free drainage. Over the edge drainage is not compatible where noise mitigation barriers/bunds are required. Refer to Series 700 of TII SCD for pavement edge details and the maximum allowable drop from the carriageway edge.

3.8 Grassed Surface Water Channels

Grassed channels are a development of swales for use as road edge channels. They are becoming increasingly common due to their potential to control both storm water runoff rates and pollution. They are considered a sustainable drainage system (SuDS) and offer a number of environmental benefits including; a potential habitat for local fauna coupled with a better aesthetic value. Therefore, they should generally be first preference when considering road edge drainage systems. The grassed surface water channel usually consists of a grassed triangular or trapezoidal surface water channel that is installed at the pavement edge to collect and convey rainfall runoff from the road surface. TII DN-DNG-03073 gives further guidance on their design.

3.9 Effects of Pavement Overlays on Drainage Edge Details

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

3.9.1 Kerbs and Gullies and Combined 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.

Alterations in level of precast concrete kerb 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 consider the relative economics of an alternative solution comprising reconstruction of the adjacent pavement.

3.9.2 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 break-out 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.

3.10 Porous Asphalt Surfacing Course

Series 900 of TII SPW Road Pavements – Bituminous Materials set out the standards for the usage of porous asphalt.

3.11 Combined Surface and Sub-Surface Drains

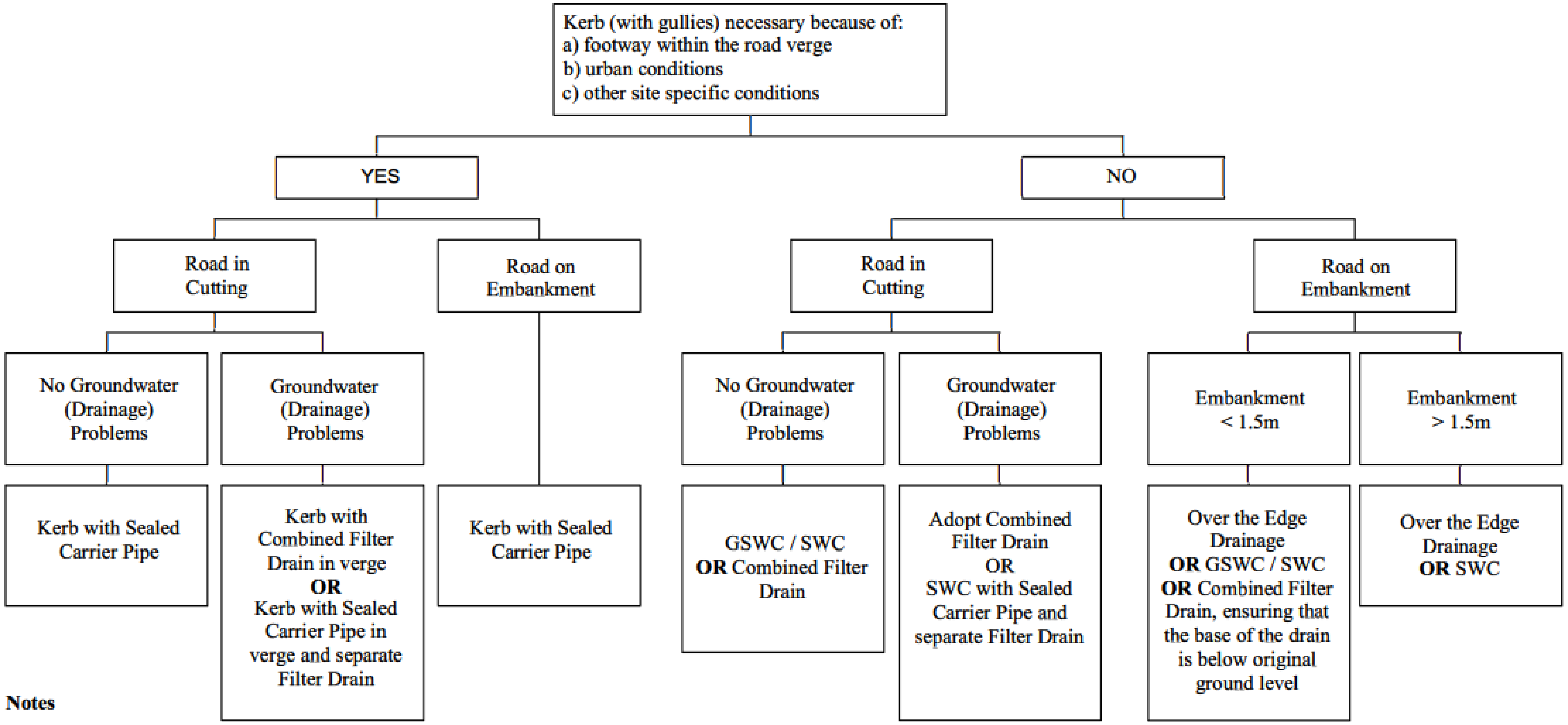
Combined surface and sub-surface drains alongside the carriageway have been in use for many years and due to the very open texture of the filter material provide for the rapid removal of rainwater from the road and verge surface and also the removal of sediment washed from the carriageway surface. Because the pipe diameters are relatively large, there is, except in rare instances, exceptionally large groundwater capacity which extends as a cut-off to below the capping layer. Therefore, combined surface and sub-surface drains are likely to be the best solution in cuttings where high groundwater flows are anticipated. Measures shall be taken in the execution and completion of the Works to avoid stone scatter. See section 4.6 and CC-SCD-00520 for typical details.

Table 3.1 - General Applications of Edge Drainage Details

Drainage Collector Detail	Kerbs and Gullies	Combined Kerb and Drainage Blocks	Linear Drainage Channels	Surface Water Channels	Combined Surface and Groundwater Filter Drains	Over the Edge Drains	Grassed Surface Water Channels
Urban Applications (Reference documents)	General usage TII DN-DNG-03067	Congested public utility services, shallow outfalls, flat longitudinal gradients.	Car park areas, adjacent to vertical concrete barriers, nosings of interchanges TII DN-GEO-03031 TII DN-DNG-03061	Not generally applicable	Not generally applicable	Not generally applicable	Not generally applicable
Rural Applications (Reference documents)	Footways within road verge e.g. laybys Roundabouts (See Note 1) TII DN-DNG-03067	Flat longitudinal gradients where footways within road verge, roundabouts	Nosings of interchanges, vertical concrete barriers TII DN-GEO-03031 TII DN-DNG-03061	High-speed roads TII DN-GEO-03031 TII DN-DNG-03061 TII DN-DNG-03062	Especially in cutting verge TII DN-DNG-03062	In verges TII DN-DNG-03062	In verges TII DN-DNG-03073

Notes:

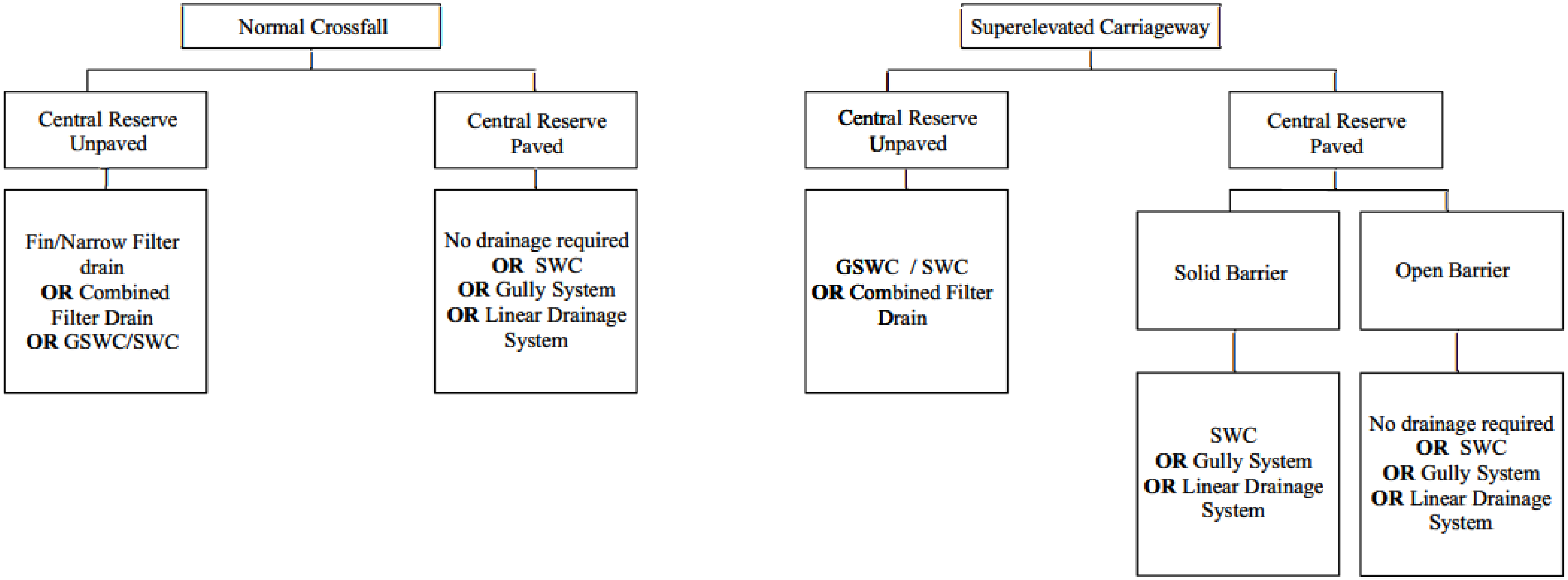
1. Kerbs and gullies are not recommended for rural roads unless footways are located within the verge.



Notes

1. Alternative drainage arrangements to those indicated above require an approved departure from standard/aspect not covered by standard.
2. A separate sub-surface drain shall be incorporated with all drainage options shown in this figure with the exception of a Combined Filter Drain. Separate sub-surface drains include the choice of Fin Drain, Narrow Filter Drain and Extension of Capping Layer. Extended capping is only allowable where the base of the extended capping layer is above the adjacent ground level and not subject to groundwater inundation. Fin Drain usage with road gullies should only be permitted if gully connections have no adverse effect on the Fin Drain.
3. GSWC denotes a Grassed Surface Water Channel and SWC denotes a concrete Surface Water Channel. Drainage channel blocks may only be used as an alternative to GSWC & SWC where sufficient distance between the channel and pavement edge is present in accordance with DN-DNG-03062 and CC-SCD-00108.
4. Kerbed Drainage Systems include Kerb & Gully system, Combined Kerb & Drainage system, and Kerb & Drainage Channel Blocks. Linear Drainage Channels are not permitted in verge-side edge drainage.
5. Careful consideration should be given to the type of drainage system to be used in conjunction with the pollution protection assessments provided in DN-DNG-03065. Site specific conditions for an 'impermeable system' may preclude some of the options provided above. Refer to sections 1. 4, 4. 5 and 4. 6.
6. Groundwater (Drainage) Problems refer to those areas where there is a risk of rising groundwater levels saturating the 300mm zone below pavement formation level (or sub-formation level if a capping is present).

Figure 3.1 - Design Options for Verge-side Edge Drainage



Notes

1. Alternative drainage arrangements to those indicated above require an approved departure from standard/aspect not covered by standard.
2. A separate Fin drain or Narrow filter drain shall be incorporated with all drainage options shown in this figure with the exception of the 'Fin/Narrow Filter drain', the 'No drainage required', and 'Combined filter drain' options. Fin Drain usage with road gullies should only be permitted if gully connections have no adverse effect on the Fin Drain. Consideration for two longitudinal Fin or Narrow filter drains should be given to central reserves greater than 6m in width.
3. Where 'No drainage required' is stated above, suitable assessment of groundwater problems and aquaplaning potential may deem drainage necessary.
4. Groundwater (Drainage) problems refer to those areas where there is a risk of rising groundwater levels saturating the 300mm zone below pavement formation level (or sub-formation level if a capping is present).
5. GSWC denotes a Grassed Surface Water Channel and SWC denotes a concrete Surface Water Channel. Drainage channel blocks may only be used as an alternative to GSWC & SWC where sufficient distance between the channel and pavement edge is present in accordance with DN-DNG-03062 and CC-SCD-00108.
6. Careful consideration should be given to the type of drainage system to be used in conjunction with the pollution protection assessments provided in DN-DNG-03065. Site specific conditions for an 'impermeable system' may preclude some of the options provided above. Refer to sections 1.4, 4.5 and 4.6.
7. A solid barrier denotes a system that doesn't allow runoff to pass through such as a solid concrete barrier or a raised, kerbed central reserve. An open barrier denotes a system that allows runoff to pass through such a wire rope or steel barrier.
8. In some instances a central reserve may have two solid barriers and careful consideration should be given to the area between the two barriers in terms of drainage and maintenance.

Figure 3.2 - Design Options for Central Reserve Drainage

Table 3.2 - Surface & Subsurface Drainage – Guidance Documents

TII Publications – Construction & Commissioning (CC)
TII SPW TII GSW TII SCD

TII Publications – Design (DN)				
Structures (STR)	Earthworks (ERW) & Drainage (DNG)	Geometry GEO)		Pavement (PAV)
TII DN-STR-03012: Design for Durability	TII DN-DNG-03062: Edge of Pavement Details TII DN-DNG-03068: Hydraulic Design of Road-Edge Surface Water Channels TII DN-DNG-03070: Determination of Pipe & Bedding Combinations for Drainage Works TII DN-DNG-03061: Design of Outfalls for Surface Water Channels TII DN-STY-03069: Safety Aspects of Road-Edge Drainage Features TII DN-DNG-03067: Spacing of Road Gullies TII DN-DNG-03063: Vegetated Drainage Systems for Highway Runoff TII DN-DNG-03064: Drainage of Runoff from Natural Catchments	TII DN-GEO-03031: Rural Road Link Design	TII DN-GEO-03060: Geometric Design of Junctions	TII DN-PAV-03021: Analytic Pavement and Foundation Design

TII Publications – Construction & Commissioning (CC)	**TII Publications – Design (DN)**				
		TII DN-DNG-03072: Design of Soakaways TII DN-DNG-03073: Grassed Surface Water Channels for Road Runoff TII DN-DNG-03071: Design of Outfall and Culvert Details TII DN-DNG-03065: Road Drainage and the Water Environment TII DN-DNG-03066: Design of Earthworks Drainage, Network Drainage, Attenuation and Pollution Control			

Notes:

1. Also see TII Environmental Assessment and Construction guidelines.

4. Sub-Surface Drainage

4.1 Introduction

Sub-surface drainage of road pavements comprises the measures incorporated in the design in order to control levels of groundwater, and drain the road foundation.

Requirements for sub-surface drainage are illustrated in Series 100 and 500 of TII SCD. 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 extension of the capping layer to the full width of embankment as illustrated in Series 100 of TII SCD, or by provision of fin or narrow filter drains as illustrated in Series 500 of TII SCD.

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. Refer to TII DN-DNG-03066 for further guidance on drainage design in areas of high groundwater levels.

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

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.

It is also essential that water is not retained within the sub-base and for that matter the capping layer. Water reaching the formation and sub-formation must be drained to longitudinal sub-surface drains by adequate shaping of the formation and sub-formation such that no undrainable low spots occur.

Circumstances in which sub-surface drainage may be omitted are described in TII DN-DNG-03062.

4.2 Groundwater Considerations

TII DN-PAV-03021 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. TII DN-PAV-03021 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.

The minimum depth of installation of fin and narrow filter drains shall be DN+50mm to invert beneath sub-formation level, or 600mm to the invert beneath formation level: these levels being defined in the Series 600 of TII SPW. Where this is no capping layer, the drains should 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. To achieve even the ‘high’ water table level will require the fin or narrow filter drain to be installed at an appreciably greater depth than the minimum shown in Series 500 of TII SCD. In situations where large volumes of groundwater are anticipated filter drains can provide a better solution than fin or narrow filter drains. TII DN-DNG-03066 provides further guidance for drainage design with high groundwater flows.

The designer shall account for the reduced capacity of the drainage system due to the groundwater baseflows when modelling storm events and shall demonstrate the adequate lowering of the groundwater table level through the sub-surface drainage design.

A further consideration is that a fin or narrow filter drain will normally follow the longitudinal profile of the carriageway and it is therefore essential, especially in flat or gently undulating conditions, that the designer ensures that the drains can discharge from all low points to a suitable outfall.

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

4.3 Sub-surface Drainage of Roads in Cuttings

The general philosophy of good road drainage is that surface water be kept separate from sub-surface water in order to prevent large amounts of water being introduced into the road at foundation level. It is not always practicable to achieve this philosophy. For example, in the case of cuttings there are many benefits that can accrue from the provision of combined filter drains. These include:

a) 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;

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

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

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

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

Combined 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.

4.4 Sub-surface Drainage of Roads on Embankment

Drainage of pavement layers of roads on embankment is effected by fin drains, narrow filter drains or extended capping contiguous to the edge of the pavement as shown in Series 100 and 500 of TII SCD, and as explained in TII DN-DNG-03062.

4.5 Relative Characteristics of Combined and Separate Systems

TII DN-DNG-03062 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.

The differences in principle between combined and separate road drainage systems are defined in Chapter 1 of this Standard. These differences are described in greater detail in the following text.

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 as necessary. 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.

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 drainage and kerb blocks, road gullies and linear drainage channels. Sub-surface drainage associated with separate collection of surface water runoff is effected by either filter drain, fin or narrow filter drains defined in Series 500 of TII SPW and Series 500 of TII SCD. Refer to TII DN-DNG-03065 for guidance on the groundwater protection response.

The verge space requirements for separate systems will typically exceed those for a combined system. As noted in paragraph 3.2, it is often difficult to provide a filter drain and a separate surface water carrier drain within a normal verge width in cuttings with high groundwater flows. While there will generally be justification to adopt combined surface and groundwater filter drains in such circumstances, there may be instances where separate systems are deemed necessary. This may occur, for example, where groundwater is vulnerable to contamination by routine road runoff, requiring an impermeable or sealed surface water drainage system (refer to DN-DNG-03065). In such cases where sealed surface water systems are required in the interests of pollution control, in conjunction with conventional deep filter drains to manage groundwater, the assembly and space requirements within the verge need to be carefully considered. As such, it may be necessary in such cases to widen the standard minimum road verge widths (as given in DN-GEO-03036) to accommodate separate drainage systems alongside other verge infrastructure such as ducts and road restraint systems.

4.6 Combined Drains

Combined drains have been a traditional solution for many years and possible problems in performance are commented upon in TII DN-DNG-03062. These include those of stone scatter, surface failures of embankments, pavement failures and safety and maintenance problems. Stone scatter from verge drains, where a hard shoulder of 2.5m or more width separates the verge from the carriageway may not normally be a problem, but they can present a safety hazard when the hard shoulder is used as running lane in contraflow. Stone scatter from central reserve drains presents a greater safety hazard.

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

a) spraying of the top surface of exposed filter material with bitumen;
b) possible usage of bitumen bonded filter material in the top 200mm of the trench;
c) the use of geogrids to reinforce the surface layer of the filter material.

The inclusion of a geogrid shall be specified in accordance with CC-SCD-00520 at locations that are likely to be subjected to vehicular overrun. As a minimum geogrid shall be specified at the following locations:

a) where the hard shoulder or hard strip is less than 2.5m;
b) lay-bys extended 30m either side of lay-by;

c) approaches to slip roads extended 50m prior to approach;

d) toll plazas.

Combined 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. TII DN-DNG-03066 provides further guidance for drainage design with high groundwater flows. It should be noted that if an impermeable drainage system is required (TII DN-DNG-03065) and if it is in an area with Groundwater (Drainage) Problems, a narrow filter may not have sufficient capacity so a filter drain may be required but shall be kept separate from the impermeable surface drainage system.

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.

4.7 Separate System: Fin Drains

4.7.1 Types 5, 6 and 7 Fin Drains

Detailed guidance is given in Series 500 TII GSW. It is intended that the widest possible choice of fin drain type should be available to the Contractor.

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.

If it is proposed to use fin drains in conjunction with kerbs and gully pavement edge drainage, care must be taken to ensure that construction of gully connections will 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.

4.7.2 Type 10 Fin Drain

TII DN-DNG-03062 specifies use of a Type 10 drain with rigid carriageways. The designer should decide whether particular scheme specific pavement materials warrant its adoption with flexible construction.

4.8 Separate System: Narrow Filter Drains

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 TII GSW, 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.

4.9 Separate System: Extended Capping Layer

Extended capping layer consists of the extension of the pavement capping material to the edge of embankment and is only allowable where the base of the extended capping layer is above the adjacent ground level and not subject to groundwater inundation. Extended capping layer provides a useful alternative to Fin Drains and Narrow Filter Drains and does not require pipe conduits or access structures for conveyance or maintenance.

4.10 Pavement Life

There are factors pertinent to drainage at construction stage that have a bearing upon the life of a pavement. The subgrade material may be subjected to more onerous conditions during the construction stage than during the service life of the pavement, and so must be sufficiently strong to provide an adequate platform for construction of the sub-base. 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. TII DN-PAV-03021 defines requirements of the road foundation. It is imperative that groundwater drainage and sub-grade drainage should prevent plastic deformation of the road foundations, sub-base and capping layer during construction, and it is recommended that consideration be given towards pre-earthworks drainage in all projects where this might be feasible.

5. Earthworks Drainage

5.1 Toe Drainage and Cut-off Drains

It is essential that existing land drainage and runoff from external catchments be taken into account in the design of road drainage. See TII DN-DNG-03064 for specific guidance.

The requirements of the appropriate regulatory authorities including Environmental Protection Agency (EPA), Inland Fisheries Ireland (IFI), the Office of Public Works (OPW) and the local authority should be established to ensure that their requests are accommodated, and their reasonable interests safeguarded. Information on ground water conditions must be included in the data obtained from site investigations for proposed major roadworks.

Where surface water and sub-surface water from adjoining land will flow 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 comparative cheapness.

All run off from the existing land drainage system should be kept entirely separate from the carriageway drainage systems where practicable and surface water from the external catchment should not be connected to the road drainage system to avoid oversized attenuation and treatment system provisions.

Where there is an existing connection of external drainage to the road drainage, either historical or by agreement, the right to connection may be permitted to continue provided that the land use of the contributing catchment of the connection remains unaltered.

It is imperative that the geotechnical Engineer evaluates the effect of such proposed ditches at an early stage, as large off-sets 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.

It is good practice to carry out drainage works at the earliest possible stage in the construction of any new road. Longitudinal drains should be sufficiently deep to collect whatever drainage is necessary at cut/fill zones and it will be necessary to give special attention to the treatment and collection by sub-soil drains of water from any water-bearing seams which are intercepted by cuttings. Intercepting drains or ditches must be sufficiently deep to intercept any system of severed agricultural under-drainage.

Watercourses and ditches crossed by a major road are generally bridged or culverted. TII DN-DNG-03064 provides specific guidance on dealing with the drainage of natural catchments and TII DN-DNG-03071 gives detailed guidance on outfall and culvert design.

The need for slope drainage should be determined prior to the start of construction in order to minimise difficulties in the future connection of slope drains into longitudinal verge drains.

5.2 Drainage to Retaining Structures

Requirements for drainage of retaining structures are set out in TII DN-STR-03012.

6. Detailed Design, Pavement Edge Drainage

6.1 Introduction

Detailed design of pavement drainage comprises seven basic aspects:

a) consideration of pollution and flood risk requirements;

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

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

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

e) determination of the location of the outfalls or soakaways;

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

g) specification of appropriate chambers and covers.

6.2 Storm Return Period

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

Transverse sealed drains, including gully connections, crossing beneath the carriageway, shall be designed to accommodate a 1 in 50 year storm without surcharge or be a minimum of 300mm, whichever is greater.

Combined surface water and ground water drains must also be designed to accommodate a one-year storm in-bore without surcharge. A design check must 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.

Guidance on the design of surface water channels is given in TII DN-DNG-03062. The fundamental philosophy of this document 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 carriageway.

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 in accordance with Chapter 2.

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: The rainfall intensities used in the design of drainage systems must be increased by 20% in order to allow for the future effects of climate change.

Rainfall data should be obtained directly from Met Éireann in the first instance however 2minM5 values required in TII DN-DNG-03068, TII DN-DNG-03067 and TII DN-DNG-03073 are not available from Met Éireann and therefore M5-2D, M5-60 and r values to derive 2minM5 values shall be estimated from maps included in the Flood Studies Report, (NERC, 1975).

Application of storms of other return periods should be tempered by considerations of geography and particular road geometry. Examples of critical sections of road are quoted in TII DN-DNG-03068 as:

a) applications of superelevation that cause crossfall to be locally zero; and
b) sections of road draining to longitudinal sag points where it is important to prevent flooding.

This is especially important for longitudinal sags in cuttings, where potential for excessive flooding of the carriageway is likely. The system shall ensure that water depth at the kerb or edge of pavement, measured from pavement level, does not exceed 250mm during a 1 in 50 year storm.

6.3 Calculation of Runoff Flows

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.

Over the years, drainage designers have been using a number of established procedures for calculating runoff. However, the most commonly used procedure in the Republic of Ireland is the Wallingford Procedure first published in 1981. 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.

A number of commercial programs based upon the Wallingford Procedure are available and suitable for road 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.

6.4 Chambers

Chambers shall include all drainage Manholes and Catchpits. The location of drainage chambers and the associated underground pipelines can vary due to the presence of other roadside items such as traffic signals, road safety barrier systems and underground utility services. Chambers should always be located outside the carriageway. Where the chambers are not able to be located within the verge, then it is desirable to locate chambers outside of wheel paths to minimise damage to the drainage infrastructure and the vehicles. A departure from standard shall be required for any chambers located in the carriageway.

Chambers are required at the following locations:

a) at maximum 100m spacing;
b) at changes of direction, grade, level or size of pipe;
c) at pipe junctions.

In locations where the chamber is collecting surface water runoff, the chamber shall be a Catchpit in accordance with Series 500 of TII SCD.

6.5 Gully Systems

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 determined by considerations of the maximum width of flow that can be permitted in a channel fronting a raised kerb; this criterion is set out in Chapter 2. Additionally the maximum flow rate entering the gully shall be less than 15 litres/s if it has a diameter of 150mm as this is the maximum flow the gully pot can accept without surcharge. It is necessary for the Designer to include details of gully grating specifications in the Contract in Appendix 5/1, and the comments in paragraph 6.10 are pertinent to structural considerations of traffic loadings to which gullies are subject.

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 should comply with Class D400 of I.S EN 124 to withstand trafficking of the hard shoulder during maintenance operations.

6.6 Surface Water Channels

Design of surface water channels is described in principle in TII DN-DNG-03062. Design of the channels in cross-section to achieve the necessary hydraulic capacities is set out in TII DN-DNG-03068; cross-sections are illustrated in Series 500 of TII SCD. 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.

Surface water channels generally occupy a larger proportion of the available verge or central reserve width than do other common drainage systems. 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.

It is necessary to outlet surface water channels whenever they reach capacity, and if suitable outlets are not available carrier pipes become necessary. When discharge into a longitudinal carrier pipe has become necessary, outlets shall be designed in accordance with TII DN-DNG-03061. 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 road cross-section.

The design method of TII DN-DNG-03068 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, TII DN-DNG-03068 should be used to determine the spacing between the outlets, which, in turn, should be designed according to the recommendations of TII DN-DNG-03061.

6.7 Combined Kerb and Drainage System

Combined kerb and drainage blocks were commented upon in principle in Chapter 3. Specification for these is set out in Series 500 of TII SPW. This requires the Designer to specify particular requirements with respect to dimensions and strength of the units and their hydraulic design parameters. The Designer should obtain the approval of the Transport Infrastructure Ireland to the content and inclusion of the Specification proposed. Proprietary combined kerb and drainage should be examined, and in the interests of commercial benefit the specification should be as wide as possible to maximise competition.

Each manufacturer produces comprehensive literature of the product and this will include statements and a design guide to the hydraulic capacity of this 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 blocks is not possible. Different flow theories are used in each case, the most extreme disparity being that part flooding of the carriageway is accepted and essential 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 and document their verification of the hydraulics for the combined network scenario.

6.8 Manufactured Linear Drainage Channels

Series 500 of TII SPW sets out the specification for linear drainage channels. Manufactured units have been available in Ireland for a number of years and have been used 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. Some units may be unsuitable for areas of pedestrian and cyclist usage and shall be precluded from the design if a safety risk is identified.

6.9 In Situ Concrete Linear Drainage Channels

This form of construction has been extensively used, primarily by slip forming, on major roads on the Continent. Development and practice in Ireland 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.

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

There are considerable differences in the tolerances and quality control that can be achieved with in situ construction relative to pre-cast. 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.

6.10 Pipe Design

6.10.1 Hydraulic

Hydraulic design of a pipe network is generally accomplished by computer application of the principles described earlier in this Chapter.

Minimum pipe diameter shall be 225 millimetres except for gully connections which may be a minimum of 150 millimetre in diameter.

Pipe (including combined kerb and drainage blocks, manufactured linear drainage channels and in situ concrete linear drainage channels) flow velocities shall not be less than 0.75 metres per second for a 1 in 1 year storm at any point or greater than 2.5 metres per second at discharge points unless adequate scour protection is provided. It should be noted that scour protection may be required for flow velocities less than 2.5 metres per second (refer to TII DN-DNG-03071). Further guidance on minimum self-cleansing velocities can be found in CIRIA R141.

6.10.2 Structural

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

a) A Guide to Design Loadings for Buried Rigid Pipes; and
b) Simplified Tables of External Loads on Buried Pipelines.

Guidance on permissible combinations of pipe and bedding materials is set out in TII DN-DNG-03070.

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, precast concrete and flexible pipes of uPVC, polyethylene and polypropylene. TII GSW guides upon necessary specifications for plastics pipes, and also upon exclusions or special treatments necessary to withstand chemical attack because of groundwater conditions.

Analysis of pipes outside of this range will require recourse to other guidance documents. 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 Foundation for Water Research's publication 'Materials Selection Manual for Sewers, Pumping Mains and Manholes'.

The Series 500 of TII SPW permits the use of other types of pipe, such as twin-walled PVC, provided that they are supported by an Irish Agrément Board Roads and Bridges Certificate or equivalent. Bedding combinations for such pipes are not included in TII DN-DNG-03070, but will be specified in the Agrément.

6.10.3 CCTV Surveys of Drains

TII SPW specifies requirements for testing and cleaning of drains. TII SPW requires that unless otherwise required in Appendix 29/1, all carrier, foul and filter drains shall be surveyed by Close Circuit Television (CCTV) in accordance with the relevant requirements of Series 2900 of TII SPW.

6.11 Discharges to Outfalls and Soakaways

A balance needs to be struck when considering whether road 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. Where the system outfalls to a watercourse, the final outfall (after the attenuation or treatment measures) should be set above the 1 in 5 year flood level of the watercourse. This is in order to allow the outfall discharge under free flow conditions in the 1 in 5 year flood event. Further guidance on the design of outfalls and culverts is given in TII DN-DNG-03071.

Guidance on the design and construction of soakaways is given in TII DN-DNG-03072. A number of factors must be considered in their design:

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

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

c) 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;

d) soakaways must not increase the risk of groundwater flooding.

Guidance on groundwater protection from discharges to ground is provided in TII DN-DNG-03065.

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.

All Chambers and covers shall comply with the TII SPW. Safety precautions require for chambers ⩽ 2.0m in depth that the clear opening size of the cover shall be 600mm in diameter. For deep chambers >2.0m in depth, where man access is required, openings shall be 750mm – 900mm clearway diameter in accordance with Series 500 of TII SCD to allow for operative to enter the chamber with the appropriate safety equipment such as breathing apparatus. In carriageways, hard verges and verges, chamber covers, frames and gratings should be a minimum Class D400. All covers located in the Road Pavement are to be lockable.

7. Control of Pollution and Flooding

7.1 General

Whilst the primary aims of drainage systems are to provide rapid removal of surface water from the road surface and to provide effective sub-grade drainage, the systems shall include measures to minimise the risk of accidental spillages causing pollution and shall provide for significant removal of suspended solids and other contaminants. Guidance on the assessment of pollution and flooding is given in TII DN-DNG-03065 and TII Environmental Assessment and Construction Guidelines. Table 7.1 shows which systems can provide some form of control over these risks. The drainage design, including pollution control measures, shall be developed to an adequate level of detail at Environmental Impact Assessment (EIA) stage to ensure a high level of confidence in determining land take requirements for swales, ponds and other drainage features. TII DN-DNG-03065 provides guidance for groundwater risk assessments and associated protection responses which must be assessed and incorporated at EIA stage for all schemes. The groundwater protection responses shall be reassessed and applied throughout the project lifecycle as more detailed information becomes available or design progresses/changes.

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

a) **Spillage control:** Sediment Tanks, Vortex Separators, Lagoons, Vegetated systems, Detention and Retention Ponds, Oil Separators, Penstocks, Baffles, Kerbs and Gullies, Surface Water Channels, Filter Drains, Grassed Surface Water Channel;

b) **Other pollution control:** Filter Drains, Unlined Ditches, Oil Separators, Sediment Tanks, Vegetated Systems, Detention and Retention Ponds, Sediment Forbays;

c) **Flow control:** Filter Drains, Carrier drains (oversize), Ditches, Combined Kerb and Drainage, Throttle back systems, Detention and Retention Ponds, Orifice plates, Vegetated systems, Grassed Surface Water Channel;

d) **Vegetated systems:** Detention and Retention Ponds, Infiltration Basins, Wetlands, Grassed Surface Water Channels, Swales, Over the Edge to vegetated ditches.

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 in given in TII DN-DNG-03063. Guidance on grassed surface water channels for road runoff is given in TII DN-DNG-03073. 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 shall be considered. Designers should ensure that systems such as oil separators, vortex separators and lagoons, that may be remote from the road, are provided with safe means of access for maintenance.

7.2 Flood Risk

Flood risks to a road should be assessed at the design (Phase 3 of the TII Project Management Guidelines) and environmental assessment (Phase 4) phases of a project and refined during Phases 5 and 6 in accordance with TII DN-DNG-03065.

The proposed scheme should have ‘no worsening’ of flow rates up to and including the 1 in 100 year storm. Therefore the designer shall demonstrate that post development peak discharge rates for the critical 1 in 100 year storm duration are equal or less than the peak 1 in 100 year greenfield runoff rate for the critical storm duration at the proposed scheme’s boundaries.

Generally, some form of attenuation storage is required to meet this criterion. Further guidance is given in TII DN-DNG-03066. Where there are limitations on space available to provide a suitable attenuation facility the return period requirement may be reduced but consultations with all relevant bodies and written approval from the Transport Infrastructure Ireland and the local authority must be obtained.

7.3 Control of Pollution

Significant pollutants that are routinely found in 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 TII DN-DNG-03065.

Appropriate treatment components will need to be chosen depending on the expected road 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.

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 7.1 presents the potential treatment efficiencies for the various measures for different types of contaminants, and Figure 7.1 provides guidance on the selection process.

Table 7.1 - Indicative Treatment Efficiencies of Drainage Systems

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 considered using TII DN-DNG-03065.

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 protection response assessment should be carried out using TII DN-DNG-03065.

c. Variable and negative values recorded for dissolved copper and zinc – not considered reliable for removal of dissolved metals.

d. Oil separators can only be considered for treating oils and must not be relied upon to treat suspended solids, or dissolved metals.

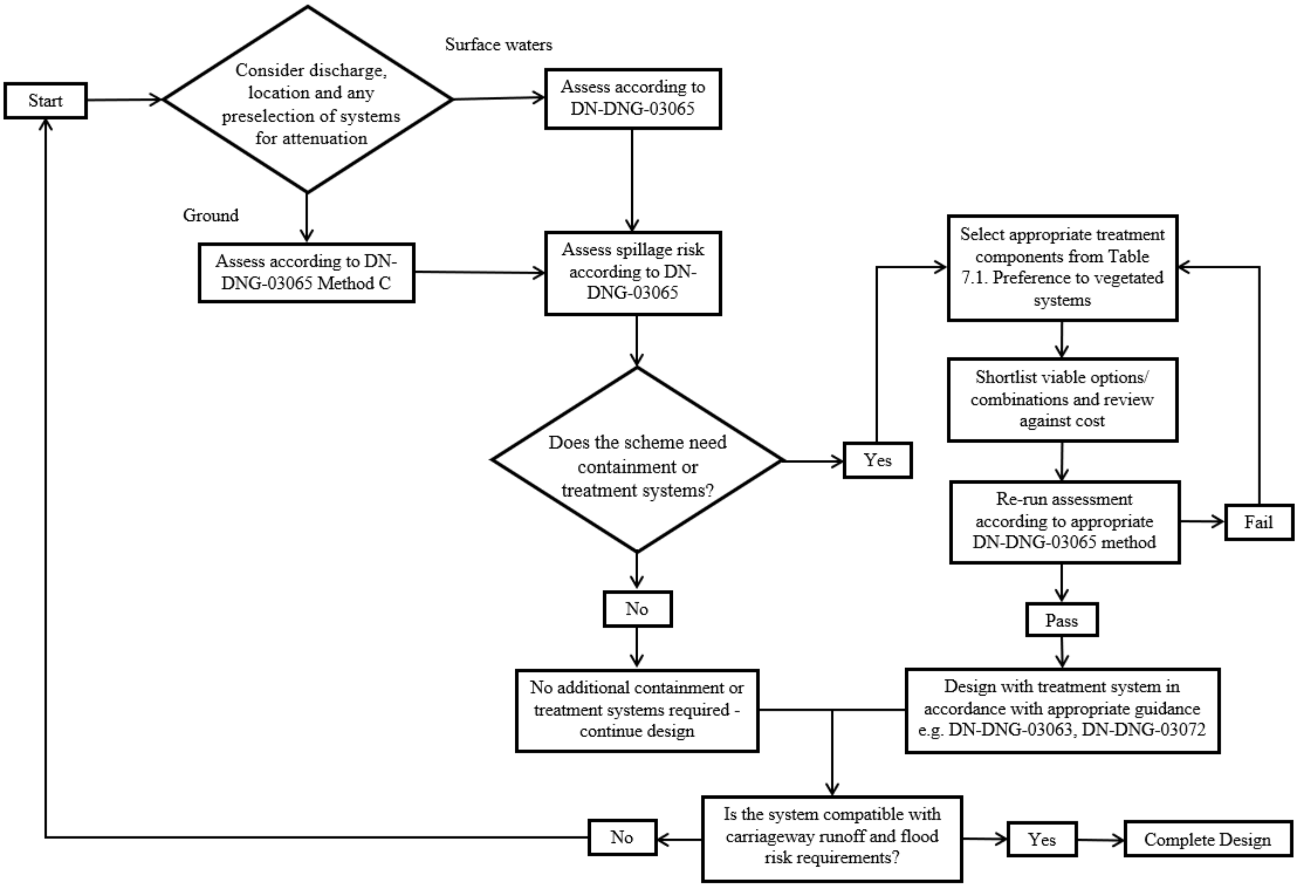


Figure 7.1 - Recommended Selection of Treatment Systems

7.4 Other Drainage Components

Whilst the treatment components described in Table 7.1 are likely to be the preferred methods for providing treatment of road runoff, the following components also continue to have a role to play, if not considered as treatment components in their own right.

7.5 Drainage Systems

7.5.1 Kerbs and Gullies

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.

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.

7.5.2 Surface Water Channels and Drainage Channel Blocks

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.

7.5.3 Combined Kerb and Drainage System

Combined kerb and drainage systems can attenuate flow, mainly due to the high storage capacity of the design. Where attenuation 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 facility.

7.5.4 Piped Systems

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. Reliance on human intervention to provide downstream control (i.e. to operate penstock or handstop) should be avoided unless demonstrated to be the only means of reasonable control.

7.5.5 Ditches

Unlined ditches have some potential to control pollution, due to infiltration of the runoff through the soil profile and any vegetation present. Ditches with gentle side slopes can be considered to have similar properties to swales, which are described in TII DN-DNG-03063. Ditches are in common use on National Roads projects, 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 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 25m3 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 road 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.

7.5.6 Over-the-Edge Drainage

Over-the-edge drainage can provide, in some circumstances, some degree of pollution control as road runoff is allowed to filter through vegetation on the slope. Field studies of vegetated strips/embankments have shown the pollutant retention was primarily a surficial phenomenon, limited to the top 500 mm of road 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.

7.5.7 Combined Surface and Sub-surface Drains

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. This, or replacement will probably be needed if contaminated by a serious accidental spillage.

The use of combined surface and sub-surface drains should always be assessed in conjunction with the risk to groundwater pollution.

7.6 Sediment/Oil Separators

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.

Full retention separators are used where all the runoff has to be treated. Their application will be very rare on roads, 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.

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 Ireland. They rely on the greatest pollutant load being carried by the “first flush” of a runoff event. Only 1% of all rainfall events in Ireland have a rainfall intensity exceeding 5mm/hour, so such interceptors will cater for the large majority of events. The Design for any petrol / oil interceptor shall conform with the recommendations of CIRIA Report 142 - Control of Pollution from Highway Drainage Discharges and shall be as a minimum Class 2 Bypass Interceptors to I.S. EN 858-1.

On rural roads, oil separators may not be the optimum solution, due to their requirement for frequent maintenance. Consideration should be given to installing a vegetated drainage system, as described in TII DN-DNG-03063, or to a less expensive containment facility.

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).

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.

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.

7.7 Other Containment Facilities

7.7.1 Sedimentation Lagoons and Tanks

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 relevant regulatory authorities including the EPA, IFI, OPW, and local authority. For more guidance on the design and selection of settlement lagoons see TII DN-DNG-03063.

7.8 Pollution Control Devices

7.8.1 Penstocks

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 road 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 local authority personnel, or road maintenance contractors. Designers must ensure that such devices can be readily located and that they are provided with safe and easy means of access.

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.

7.8.2 Handstops

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 will only be suitable for smaller systems where the plate dimensions and weight are manoeuvrable by hand without mechanical aid. As with penstocks, regular inspections and maintenance will be required.

7.8.3 Weirs, Baffles

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.

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 be a minimum 25 m3 of containment.

7.8.4 Hanging Walls

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.

7.9 Flow Control Devices

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. Designers should refer to 'The SuDS Manual' (CIRIA C753F) for guidance on flow control devices such as orifice plates.

7.10 General Attenuation Design

Consultation with relevant authorities (e.g. local authorities, the OPW, Inland Fisheries Ireland, etc.) must be carried out prior to design of attenuation so that their requirements can be incorporated into the design.

Where possible attenuation should be combined with pollution control and water quality improvement measures. A minimum spill containment volume of $25m^3$ shall be provided at locations identified in using the Spillage Risk Assessment Tool provided in TII DN-DNG-03065. Treatment Volumes for water quality improvement should be calculated with reference to TII DN-DNG-03063 and CIRIA Report 142 – Control of Pollution from Highways Drainage Discharges.

Where attenuation is provided by means of an attenuation pond a minimum freeboard of 300mm shall be provided between the maximum water level in the pond and the top level of the pond or pond protection bund. Where attenuation is ponds are located in areas liable to flooding, e.g. the floodplains of watercourses, an assessment of the impact of the pond on the hydraulic regime of the watercourse shall be undertaken and the pond bunded to a level 500mm above the 1 in 100 year flood level. The TII NGSPW contain guidance on some of the requirements for attenuation ponds and may be of use to designers considering the issues which need to be taken into account as part of the attenuation design.

8. References

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a) TII Specification for Works (TII SPW)
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c) Standard Construction Details (TII SCD)

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a) TII DN-DNG-03070 Determination of Pipe and Bedding Combinations for Drainage Works
b) TII DN-DNG-03068 Hydraulic Design of Road Edge Surface Water Channels
c) TII DN-DNG-03066 Design of Earthworks Drainage, Network Drainage, Attenuation and Pollution Control
d) TII DN-DNG-03062 Edge of Pavement Details
e) TII DN-DNG-03065 Road Drainage and the Water Environment
f) TII DN-DNG-03061 Design of Outfalls for Surface Water Channels
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h) TII DN-DNG-03067 Spacing of Road Gullies
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m) TII DN-DNG-03073 Grassed Surface Water Channels for Road Runoff
n) TII DN-GEO-03031 Rural Road Link Design
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