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Transport Infrastructure Ireland

TII Publications

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Road Drainage and the Water Environment (including Amendment No. 1 dated June 2015)

DN-DNG-03065
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DN Design

Standards

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Volume 4 Section 2
Part 1
NRA HD 45/15

An tÚdarás um Bóithre Náisiúnta
National Roads Authority

Road Drainage and the Water Environment

(including Amendment No. 1)

March 2015 (including Amendment No. 1, dated June 2015)

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Summary:

This Standard gives guidance on the assessment and management of the impacts that road projects may have on the water environment. These include possible impacts on the quality of water bodies and on the existing hydrology of the catchments through which roads pass. Where appropriate, the Standard may be applied to existing roads.

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VOLUME 4 GEOTECHNICS AND DRAINAGE

SECTION 2 DRAINAGE

PART 1

NRA HD 45/15

ROAD DRAINAGE AND THE WATER ENVIRONMENT (INCLUDING AMENDMENT NO. 1)

Contents

1. INTRODUCTION

Background

1.1 Water is vital for all living plants and animals. For human beings it is not only essential to life and health, but also of crucial importance in industry and agriculture, for waste disposal, as a means of transport and for informal recreation and organised sports. Maintaining and, where justified, improving the quality of Ireland's drinking water, surface waters, groundwater and coastal waters is paramount in priority. There is also great importance with regard to the management of flood risk in the planning process, acting on a precautionary basis and taking account of climate change. To achieve these aims, it is necessary to set standards for protection of the water environment, make regulations to prevent its degradation and issue advice on how it can be avoided.

1.2 Roads are designed to drain freely to prevent build-up of standing water on the carriageway whilst avoiding exposure to or causing flooding. Contaminants deposited on the road surface are quickly washed off during rainfall. Where traffic levels are high the level of contamination increases and therefore, the potential for unacceptable harm being caused to the receiving water also increases. Although there are many circumstances in which runoff from roads is likely to have no discernible effect, a precautionary and best practice approach indicates the need for the assessment of the possible impact of discharges from proposed National Roads.

1.3 The 2015 revision of the NRA's drainage standards was precipitated by post-doctoral research carried out under the NRA's Research Fellowship Programme and mentored by the NRA'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 NRA'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* (NRA, 2014) documents this research and provides useful background reading to the NRA's drainage standards. This document is available at: nrastandards.nra.ie/latest/other-nra-documents.

Scope

1.4 The principles outlined in this Standard apply to all National Roads projects.

1.5 This Standard gives guidance on the assessment and management of the impacts that new construction and improvement projects may have on the water environment. These include possible impacts on the quality of water bodies and on the existing hydrology of the catchments through which roads pass. The Standard considers four principal areas:

a) Effects of Routine Runoff on Surface Waters;

b) Effects of Routine Runoff on Groundwater;

c) Pollution Impacts from Spillages; and

d) Assessing Flood Impacts.

1.6 The assessment techniques described in this Part are associated with discharges to water bodies from the development and/or improvement of National Roads projects in Ireland but can be applied wherever surface or groundwater resources are affected by road runoff.

1.7 It should be recognised that assessments made for water quality should, where appropriate, be considered in context with the Environmental Impact Assessment (EIA) process as a whole. For further guidance reference should be made to the NRA Project Management Guidelines (NRA PMG), NRA Environmental Impact Assessment of National Road Schemes – A Practical Guide and the NRA Environmental Assessment and Construction Guidelines.

Purpose

1.8 Methods are provided in Appendix A for predicting the potential impact of proposed road projects on the water environment. The methods are intended to be used throughout the lifespan of a project, used at every stage from the initial environmental assessment process through to construction, to provide the most objective and structured evaluation of the potential impacts of proposed road projects, and hence ensuring that:

a) the need for the avoidance, and reduction, of impacts on the water environment is taken fully into account in the environmental evaluation of projects and in route selection; and

b) the selection of appropriate means of preventing any significant predicted impacts of the chosen route is made, through modification of the drainage design, choice of discharge location(s) and/or adoption of runoff treatment methods, with the objective of designing out potential adverse environmental impacts.

Implementation

1.9 [1]This Standard shall be used forthwith on all schemes for the construction and/or improvement of national roads except where the scheme has received, prior to publication of this Standard, its statutory approvals to allow it to proceed. If this exception applies, the standard to be used may be either this current Standard or the Standard applicable preceding the March 2015 version of the Standard. Where the previous Standard is to be used, Designers Organisations shall confirm this by e-mail to the Standards Section of the National Roads Authority at infoDMRB@tii.ie.

Definitions and Abbreviations

1.10 Pollution from road drainage can arise from a variety of sources including: collisions, general vehicle and road degradation, incomplete fuel combustion, leaks of oil, fuel or other pollutants, fires and atmospheric deposition. Road runoff may also contain runoff from adjacent properties, and in rural areas from agricultural land. The following terms are commonly used to define types of pollution and are used in this Standard:

a) **Diffuse Pollution** arises from widespread activities, for example herbicide/salt application, or from numerous small point source discharges. Typical point sources are sewage or industrial discharges. Pollution resulting from road runoff can be considered as diffuse or point source pollution. Pollution may be either acute or chronic in its effects on aquatic organisms.

b) **Acute Pollution** occurs as a result of a severe, usually transient, impact. For road runoff, these impacts usually result from a spillage of pollutants, but can result from routine runoff. High loads of suspended solids may have similar effects in certain circumstances. The impacts are generally associated with readily dissolved forms of the pollutants which, on discharge into the water environment, are sufficiently toxic above certain concentrations to result in the death of organisms over a relatively short period of time (usually hours/days).

c) **Chronic Pollution** is the result of on-going low levels of pollution which may result in the accumulation of sediment-bound pollutants over a longer period of time (months/years).

[1] *Amended as per Amendment No. 1, item 1*

These low levels of pollutants can result in non-lethal effects, such as reduced feeding, growth rates and reproduction, or may result in the death of organisms. Sediment can also have indirect effects on ecosystems such as the burial of spawning beds and the changing of a gravel dominated substrate to a substrate dominated by finer sediments.

d) **Routine runoff** is the normal runoff from roads that may include the contaminants washed off the surface in a rainfall event and can result in either **acute** or **chronic** impacts. It excludes the effect of spillages and major leaks which usually result in acute impacts.

2. WATER RESOURCE MANAGEMENT IN IRELAND

Key Legislation and Government Policy

2.1 Water resource management in Ireland is reflected through the following key pieces of legislation:

a) The EU Water Framework Directive (WFD) 2000/60/EC;

b) The Groundwater Directive 2006/118/EC;

c) European Communities Environmental Objectives (Groundwater) Regulations 2010;

d) European Communities Environmental Objectives (Surface Water) Regulations 2009;

e) European Communities (Drinking Water) (No.2) Regulations 2007;

f) European Communities (Quality of Salmonid Waters) Regulations 1988;

g) Water Services Acts 2007 – 2013.

2.2 An outline of this and other relevant legislation is given below to explain the legal basis for the assessment of the impacts on water bodies.

The Water Framework Directive and Groundwater Daughter Directive

2.3 The WFD established a framework for management of water resources throughout the European Union. The Directive was transposed into Irish Law by means of 5 main Regulations:

a) European Communities (Water Policy) Regulations 2003;

b) European Communities Environmental Objectives (Surface Waters) Regulations 2009;

c) European Communities Environmental Objectives (Groundwater) Regulations 2010;

d) European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2010;

e) European Communities (Technical Specifications for the Chemical Analysis and Monitoring of Water Status) Regulations 2011.

2.4 The WFD is aimed to achieve good quality status in the majority of water bodies by 2015 and its key objectives, provided for in River Basin Management Plans (RBMPs), are to:

a) prevent deterioration, enhance and restore bodies of surface water, achieve good chemical and ecological status of such water and reduce pollution from discharges and emissions of hazardous substances;

b) protect, enhance and restore all bodies of groundwater, achieve good chemical and quantitative status of groundwater, prevent the pollution and deterioration of groundwater, and ensure a balance between groundwater abstraction and replenishment;

c) preserve protected areas.

2.5 The WFD places most importance on the health of animal and plant groups. It requires that the water environment be looked at as a whole, integrating water quality, quantity and physical habitat with ecological indicators. Information gathered through the Environmental Protection Agency (EPA) monitoring programmes has allowed the classification of surface water bodies into one of five WFD ecological status classes (High, Good, Moderate, Poor, Bad) and one of two chemical status classes (Pass/Fail). In addition, there is a separate classification system for groundwater, with two stages (groundwater quantitative status and groundwater chemical status), each of which has two status classes (Good/Poor). One of the main goals of the Directive is to aim for at least 'good' ecological and 'good' chemical status for surface waters, and 'good' chemical and 'good' quantitative status for groundwaters by 2015. For water bodies designated as 'artificial or heavily modified', such as canals or reservoirs, the Directive aims to achieve 'good ecological potential' rather than 'good ecological status'.

2.6 The Groundwater Directive (80/68/EEC) was repealed in 2013 and was replaced by the Groundwater Daughter Directive (2006/118/EC), now referred to as the Groundwater Directive (2006/118/EC). This Directive establishes the criteria by which groundwater chemical status is assessed, sets out the requirements for the identification of trends in groundwater quality and the mechanisms required to identify and prompt actions to bring about the reversal of downward trends in groundwater quality and requires preventing or limiting the introduction of pollutants into groundwater. Further details are available on the Department of the Environment, Community and Local Government (DECLG) website **environ.ie** (www.environ.ie) and EPA website **epa.ie** (www.epa.ie).

Flood Risk, Development and Planning

2.7 The Arterial Drainage Act of 1945 and Arterial Drainage (Amendment) Act of 1995 provide the OPW with powers for drainage and improvement of agricultural lands and the undertaking of localised flood defence schemes to reduce flood risk in urban areas. The Arterial Drainage Acts and the European Communities (Assessment and Management of Flood Risks) Regulations 2010 introduce OPW consent requirements for the creation and modification of watercourses, embankments, weirs and bridges. Under Section 50 of the Arterial Drainage Act, 1945, consent is required by bodies and persons proposing to carry out construction or alteration works on bridges and culverts. Section 9 of the Arterial Drainage (Amendment) Act, 1995, requires consent for modifications or relocations of 'relevant works' which means a watercourse, embankment or other works that has or have been completed pursuant to a drainage scheme. These should not increase the risk of flooding or have a negative impact on drainage land. This relates to regrading or relocation of watercourses, replacement or relocation of embankments. Under section 47 of the Arterial Drainage Act, 1945 consent is required for erection or alteration of a weir.

2.8 A review of national flood policy was undertaken in 2003 to 2004 and the Report of the Flood Policy Review Group was approved and published in 2004. Some of the specific recommendations included:

a) Management of flood risk rather than relying on flood protection measures to reduce flooding;

b) Take a proactive approach to managing flood risk and take a catchment based approach to managing flood risk.

These recommendations led to the development of the National Catchement Flood Risk Assessment and Management (CFRAM) programme. This commenced in 2011 and is central to the medium to long-term strategy for the reduction and management of flood risk in Ireland. It delivers on the core objectives of the National Flood Policy and the requirements of the European Union: Directive on the Assessment and Management of Flood Risks [2007/60/EC]. OPW is the national authority for the implementation of the EU 'Floods' Directive [2007/60/EC]. This is being coordinated with the requirements of the EU WFD and the current River Basin Management Plans (RBMPs). The EU 'Floods' Directive was transposed into Irish Law by S.I. 122 of the 2010 Regulations.

2.9 The Planning System and Flood Risk Management, Guidelines for Planning Authorities were published in 2009. This is a statutory document established to ensure that flood risk is properly assessed and managed as part of the planning process. As stated in the document: '*The guidelines require the planning system at national, regional and local levels to:*

a) Avoid development in areas at risk of flooding, particularly floodplains, unless there are proven wider sustainability grounds that justify appropriate development and where the flood risk can be reduced or managed to an acceptable level without increasing flood risk elsewhere;

b) Adopt a sequential approach to flood risk management when assessing the location for new development based on avoidance, reduction and mitigation of flood risk; and

c) Incorporate flood risk assessment into the process of making decisions on planning applications and planning appeals.'

The Role of Statutory Bodies

2.10 The European Communities (Water Policy) Regulations 2003 has assigned a large number of tasks to the Environmental Protection Agency (EPA), which come under the category of "corordination and oversight" of the Irish WFD programme. De facto, this has meant that the Department of the Environment, Community and Local Government (DECLG) has delegated the task of national coordination of all the technical aspects of the WFD to the EPA, while retaining ownership of the economic and policy aspects of the Directive. The Water Framework Directive Integration and Coordination Unit within the Office of Environmental Assessment (OEA) was formed in June 2014 and is responsible for WFD reporting and developing template River Basin Management Plans (RBMPs) for the identified River Basin Districts (RBDs). These RBDs are identified on a map, and are made up of a river basin or neighbouring river basins, together with associated groundwater, estuarial waters and coastal waters within 3 km. Further information can be found on the EPA's website (www.epa.ie).

2.11 In Ireland the Environmental Protection Agency Act 1992, the Protection of the Environment Act 2003 and the European Communities (Water Policy) Regulations 2003 establish EPA powers and duties for protection of water resources, amongst others. The Office of Public Works (OPW) is the State body responsible for the coordination and implementation of Government policy on the management of flood risk in Ireland and was established by the 1831 Act for the Extension and Promotion of Public Works in Ireland. The OPW are also the national authority for the implementation of the EU Directive on the Assessment and Management of Flood Risks [2007/60/EC]. In 2010 Inland Fisheries Ireland (IFI) was established as the agency responsible for the conservation, protection, management, marketing, development and improvement of inland fisheries and sea angling resources through the Inland Fisheries Act 2010. Waterways Ireland has responsibility for the management, maintenance, development and restoration of inland navigable waterways principally for recreational purposes and was established under the British Irish Agreement in 1999.

The National Parks and Wildlife Service (NPWS) is part of the Department of Arts, Heritage and the Gaeltacht (DAHG) and manages the Irish State's nature conservation responsibilities under national and European law.

Rights, Duties and Consents to Discharge to Water Bodies

2.12 In Ireland discharges to water bodies are licenced by the local authority, however there is currently no licencing requirement for discharges from roads. The European Communities Environmental Objectives (Groundwater) Regulations 2010 and European Communities Environmental Objectives (Surface Water) Regulations 2009 place duties on public authorities to promote the requirements of the regulations, and requires that sources liable to cause pollution shall be controlled so as to prevent or limit the input of pollutants.

2.13 Consultation/consent may also be required from one of the following depending on the work to be undertaken and what it interacts with:

a) EPA;

b) OPW;

c) IFI;

d) Waterways Ireland;

e) NPWS;

f) Loughs Agency.

2.14 In some situations, more stringent requirements may apply to specific water bodies. For example, those within areas designated Special Protection Areas (SPAs), Special Area of Conservation (SAC), Ramsar Wetlands or Natural Heritage Areas (NHAs) may be especially sensitive to impacts. Non-designated sites classed as salmonid waters under the Freshwater Fish Directive may also be especially sensitive to impacts. Other water bodies and related habitats inhabited by protected species may also be particularly susceptible to impacts. Consultation with the statutory nature conservation organisations will be required if these sites could be affected.

2.15 Where a body of surface or groundwater supports more than one use, the overall requirements will derive from a combination of the most stringent criteria for any of the uses concerned. No discharge which could cause any of the overall requirements to be breached will be acceptable. Hence, the assessment of new roads or road improvements should include consideration of all of the uses of a receiving water body. A surface water body should be assessed not only downstream of any discharge or river crossing, but also upstream where interests such as migratory fisheries are potentially present. During the planning and consultation process any uses as well as the appropriate water body classification defined in paragraph 2.5 and any physical constraints must be determined.

2.16 Environmental legislation is principally administered and enforced by the EPA, Regional/Local Authorities and the Minister for the Environment, Community and Local Government. In relation to water pollution, harbour authorities around Ireland and IFI also have enforcement roles. Enforcement is backed up by the court system with the vast majority of enforcement actions requiring court sanctions, as the use of administrative sanctions remains relatively undeveloped.

The key pieces of environmental legislation are:

a) Environmental Protection Agency Act 1992;

b) Protection of the Environment Act 2003;

c) Environmental (Miscellaneous Provisions) Act 2011;

d) Waste Management Acts 1996 to 2011;

e) European Communities (Environmental Liability) Regulations 2008 – 2011 (Environmental Liability Regulations);

f) COMAH. European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations 2000 – 2006;

g) Water Services Acts 2007 – 2013;

h) Dangerous Substances Acts 1972 – 1979;

i) Inland Fisheries Acts 1959 - 2010.

Surface Waters

2.17 When considering road runoff, relevant pollutants and their limiting concentrations need to be identified. Discharges from roads must not lead to a deterioration in the classification status of the receiving surface water body as determined in the relevant RBMP.

2.18 Under WFD the status of each surface water body is judged using separate 'Ecological classification' and 'Chemical classification' systems. The overall status of the water body will be determined by whichever of these is the poorer. To achieve 'good status' overall, a water body needs to achieve both good ecological and good chemical status. Further details are available on the DECLG website (www.environ.ie) and EPA website (www.epa.ie).

2.19 Under the WFD, Environmental Quality Standards (EQSs) as defined in the European Communities Environmental Objectives (Surface Water) Regulations 2009 and the DEHLG discussion document 'Rationale for Derviving national priority action, candidate relevant pollutant and candidate general component substances lists for suface waters'. Road runoff is an intermittent discharge and any breach of the annual average concentrations is only likely to persist for a short duration (minutes/hours). This may go unnoticed by standard monitoring regimes for chemical parameters but may have environmental impacts nonetheless. Research has been undertaken by the UK Highways Agency in conjunction with the UK Environment Agencies to develop a set of standards for the assessment of toxicological effects specifically related to road runoff and its intermittent nature. This research is discussed in further detail in Chapter 3 and forms the basis of the risk assessment procedure adopted for Ireland discussed in Chapter 5.

Groundwater

2.20 The Groundwater Directive (2006/118/EC) (as transposed in the Irish Groundwater Regulations 2010) and the WFD set out the key legislation that forms the basis of an assessment of the potential effects of road drainage on groundwater. The Groundwater Regulations give absolute protection to groundwaters, regardless of the presence of abstraction and associated Source Protection Area. Aquifers are regarded as valuable in their own right whether or not they are currently used for potable water supplies. Discharges to a groundwater body must:

a) prevent the introduction of hazardous substances and limit the introduction of pollutants into groundwater;

b) not compromise the existing groundwater classification (where this exists);

c) not lead to sustained downward trends in the quality of the receiving groundwater.

Currently hazardous substances are considered to be those identified in the EPA's Classification of Hazardous and Non-Hazardous Substances in Groundwater publication, 2010.

2.21 Discharges from roads must not lead to a deterioration in the classification status of the receiving groundwater as determined in the relevant RBMP.

2.22 The legislation and regulations pertinent to groundwater are described in more detail in Appendix A. However, under the WFD, groundwater classification uses two systems: 'Groundwater quantitative' status, which assesses the status of a groundwater body against whether there is sufficient water to maintain the health of the ecosystems it feeds (and assesses total abstractions against groundwater recharge), and 'Groundwater chemical status', which assesses the chemical quality against certain criteria established for each groundwater body.

2.23 The historical procedure for identifying substances that should be subject to having their input to groundwater controlled followed the approach of the European Communities Groundwater Directive (80/68/EEC). This involved identifying whether a substance belonged to the List I or List II groups or families of substances stated in the Directive. Introduction of List I substances to groundwater was prohibited and List II substances were to be controlled to prevent pollution of groundwater. However the European Communities Environmental Objectives (Groundwater) Regulations, 2010 establish a new strengthened regime for the protection of groundwater in line with the requirements of the WFD (2000/60/EC) and the Groundwater Directive (2006/118/EC). Regulation 9(c–f) requires the EPA to identify and publish a list of substances which are to be considered hazardous or non-hazardous and which the EPA considers to present an existing or potential risk of pollution. This list supersedes the previous List I and List II groups and is provided in the EPA's Classification of Hazardous and Non-Hazardous Substances in Groundwater publication, 2010. The technical requirements to meet the groundwater objectives of the WFD are set out in a number of documents that include guidance on the compliance regime (in which objective criteria are applied). These suggest that compliance with respect to the prevention of the introduction of hazardous substances should be assessed at the unsaturated zone immediately before entry into groundwater – i.e. similar to the requirements to those for hazardous substances referred to above. Compliance with respect to the limitation of other substances (that might cause pollution) may be assessed with respect to the actual or likely harmful effect to a receptor. This allows for compliance points away from the point of introduction of the polluting substance, and is interpreted as allowing for the effects of dilution (and other attenuation) within the groundwater itself. This is similar to the requirements for non-hazardous substances referred to above. The guidance suggests that harm includes impairment of potential future uses of groundwater.

2.24 The European Communities Environmental Objectives (Groundwater) Regulations 2010 and the WFD (2000/60/EC) set out the approach to groundwater protection and management in Ireland and presents a series of policies designed to protect groundwater. Where discharges to the ground are proposed, and as road drainage may be deemed to be potentially contaminated, the methodology outlined in Groundwater Protection Response for the use of permeable drain systems on road scheme (Method C) must be followed to determine if the site is suitable for discharge.

2.25 In support of its general policy statements with respect to water intended for human consumption, the EPA / Geological Survey of Ireland (GSI) defines groundwater Source Protection Areas around potable abstraction sources (springs, wells, boreholes) to protect them from pollution. These are designed as screening tools to support the EPA / GSI with respect to their responses to developers and planners. Figure 2.1 shows a typical arrangement of areas around an abstraction source. The process of revising the location of these areas is ongoing. Source Protection Areas commonly have two subdivisions that can be summarised as follows:

a) **Inner Protection Area (SI)**: Immediately adjacent to the source and based upon a 100-day travel time from any point below the water table to the source (100 days being the decay period for most biological contaminants) and a fixed radius of 300m if no study is undertaken.

b) **Outer Protection Area (SO)**: Complete catchment / zone of contribution (ZOC) with a fixed radius of 1000m if no study is undertaken.

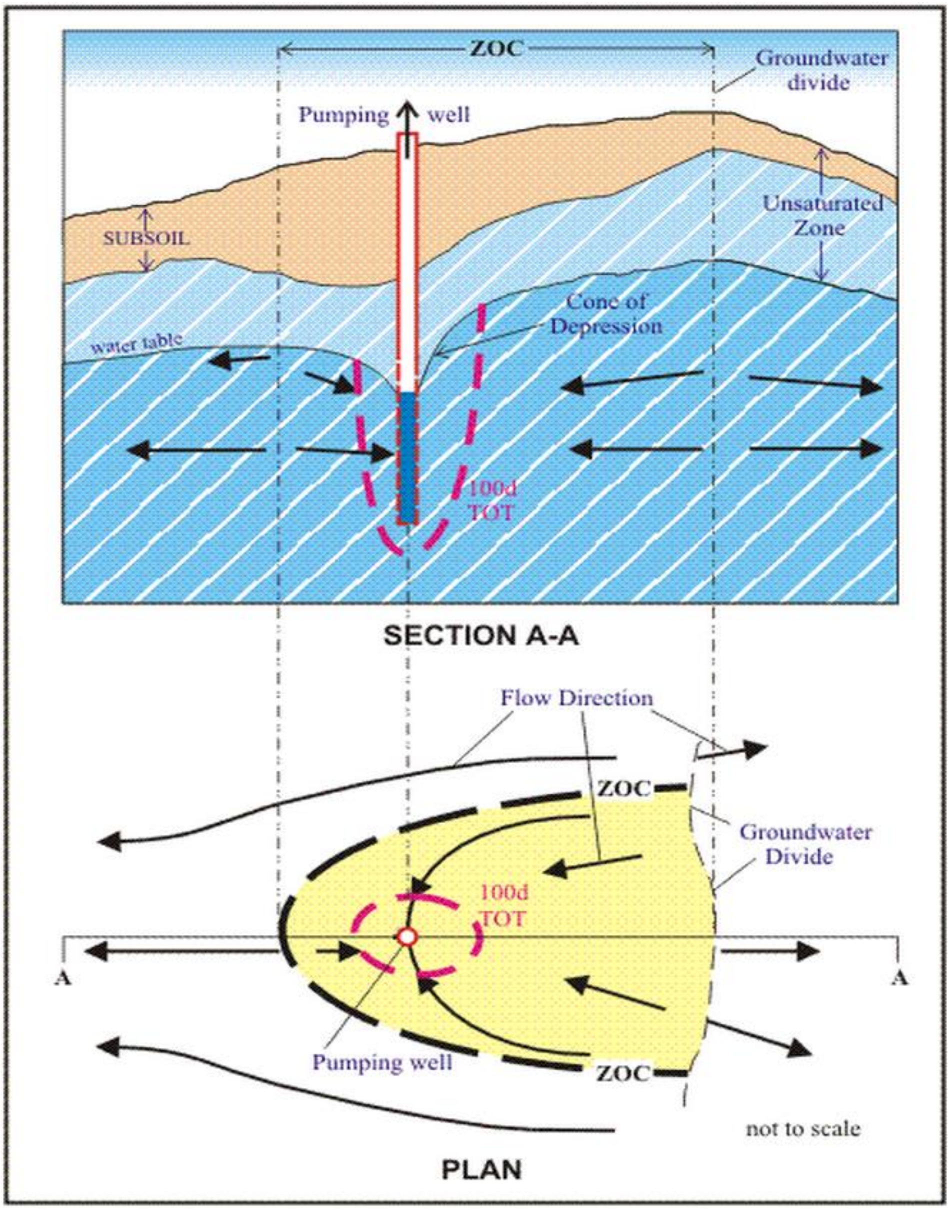

Figure 2.1: Schematic of Source Protection Areas (GSI)

2.26 The assessment of groundwater vulnerability is a key factor in determining the potential risk to an underlying groundwater body. The GSI provides relevant information and mapping of groundwater vulnerability for Ireland.

2.27 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. Similarly, if the surface water is associated with a karst feature, it is deemed as direct discharge to groundwater and in these situations a discharge to ground may be more appropriate.

Management of Spillages

2.28 When considering the risk of spillages from a road and potential pollution to the receiving environment, the following factors must be considered:

a) the calculated spillage risk return period must not be greater than 1 in 100 years;

b) the calculated spillage risk return period must not be greater than 1 in 200 years where spillage could affect protected areas for conservation, important drinking water supplies or important commercial activities; and

c) spillage risk from existing outfalls must not be increased.

2.29 When considering the impacts on water bodies from road runoff, acute pollution is most commonly associated with spillages of vehicle fuel and substances carried on roads. It can also occur on construction sites.

2.30 The management of pollution incidents usually involves the isolation of part of the road drainage system, so that the pollutant can be recovered or treated. For minor incidents, the use of booms, drain mats or absorbent materials may suffice. Larger incidents are likely to require closure of valves or penstocks, and/or blocking of outfalls/drainage ditches to avoid damage to surface waters and groundwaters. A rapid and appropriate response can often prevent a spillage from causing a severe pollution incident. All spillages that have potential to impact adversely on waterbodies should be notified to the relevant authorities. Refer to UK documents Pollution Prevention Guidelines 21 and 22 for guidance on dealing with spillages.

Management of Flood Risk

2.31 Transport infrastructure in the functional floodplain must be designed and constructed to:

a) remain operational and safe for users in times of flood;

b) result in no increased risk of flooding;

c) not impede water flows.

2.32 DECLG and OPW will liaise with regional and local authorities in assisting with technical aspects of the implementation of the The Planning System and Flood Risk Management guidelines on an ongoing basis, learning from experience within Ireland and internationally. Floodplain extents are defined by the probability of a flood event (refer to http://www.opw.ie/floodriskmanagement/ for further guidance).

3. POTENTIAL IMPACTS

General

3.1 This chapter describes possible impacts on the water environment that may arise from a road project. These may also include the potential impact to the quality of receiving water bodies, from either routine runoff or spillages. The water bodies may be either surface watercourses or groundwater. Another potential impact is the change to the risk of flooding within the catchment. The possible impact on any existing amenity or economic value of affected water bodies may also need to be considered.

3.2 There is a potential for the diffuse pollution of the water environment arising from the construction, operation and maintenance of roads. The type of pollution and consequences depend on the particular activity and local circumstances as well as the design and operational usage for any given road.

New Construction and Improvement Projects

3.3 During the construction of new or improved roads or maintenance of existing roads, pollution from mobilised suspended solids is generally the prime concern, but spillage of fuels, lubricants, hydraulic fluids and cement from construction plant may lead to incidents, especially where there are inadequate pollution mitigation measures. Other risks include:

a) water abstraction, which may cause contamination if, for example, mobilisation of existing contamination or reduced flows leads to a reduction in dissolved oxygen;

b) pollution due to vandalism of stores or plant;

c) pollution due to waste materials, dust or residues from handling contaminated land;

d) pollution from pumped discharges, for example, dewatering. These can also cause erosion.

NRA Guidelines for the Crossing of Watercourses during Construction of National Road Schemes and CIRIA 648 Control of Water Pollution from Linear Construction Projects provides advice on potential impacts arising during the construction phase and the assessment and mitigation of these risks.

Operation

3.4 A broad range of potential pollutants is associated with routine runoff from operational roads. These are combustion products of hydrocarbons, fuel and fuel additives, catalytic converter materials, metal from friction and corrosion of vehicle parts, lubricants, and materials spread during gritting and de-icing. Particulate contaminants originating from vehicles and vehicle related activities include carbon, rubber, plastics, grit, rust and metal filings.

3.5 Most organic compounds have very low solubility in water. Such compounds can occur in routine runoff and include a wide range of polycyclic aromatic hydrocarbons (PAHs). Other materials may be deposited on road surfaces such as wind-blown soils from adjacent land.

3.6 A number of UK based studies show that routine road runoff contains both dissolved and particulate contaminants. These studies have investigated the concentrations of contaminants in road runoff for a variety of road types in a number of countries. Research into the concentrations of contaminants in road runoff shows a large variation in concentrations of those contaminants detected. Applied road salt may also enhance the release of toxic metals from silts and sludge. It should be noted that the use of urea as a chemical deicer should be avoided if possible.

3.7 The UK Highways Agency (HA) has undertaken collaborative research in England with the UK Environment Agency (EA) to significantly improve the reliability and extent of existing data for pollutants and their concentrations found in road runoff from non-urban trunk roads and motorways.

The results were used to identify a list of significant pollutants that are routinely found in road runoff and which pose a risk of short-term acute impacts (from soluble pollutants) and/or long-term chronic impacts (from sediment-bound pollutants) on ecosystems. The study also identified those site characteristics that influence pollutant concentrations. A ‘significant’ pollutants list were agreed between the UK HA and the UK EA and these are listed in Table 3.1. No such list is available for Ireland however those listed in Table 3.1 can also be considered relevant and applicable to Ireland as pollutants and their concentrations found in UK road runoff will be similar or even conservative compared with the Irish scenario due to Ireland’s lower average traffic volumes. The table summarises the data from the monitoring programme for the significant pollutants showing the mean (and median) runoff concentrations found, based on Event Mean Concentrations (EMCs) from the 340 rainfall events monitored at the 30 sites sampled. The results from this research have been integrated into the assessment tools described in Chapter 5. Some studies have indicated that concentrations of pollutants may be somewhat higher in urban settings.

Table 3.1: Summary of EMCs and Loads Found in Road Runoff for Significant Pollutants (from WRc 2008)

Determinand	**Runoff Concentration**						**Runoff Load**	
	Units	**LOD**	**Min. EMC**	**Mean EMC**	**Median EMC**	**Max. EMC**	**Mean/ 1000m^2**	**Units**
Total Copper	µg/l	0.3	4.00	91.22	42.99	876.80	0.66	g
Dissolved Copper	µg/l	0.3	2.15	31.31	23.30	304.00	0.16	g
Total Zinc	µg/l	0.6	9.73	352.63	140.00	3510.00	2.44	g
Dissolved Zinc	µg/l	0.6	4.99	111.09	58.27	1360.00	0.50	g
Total Cadmium	µg/l	0.01	<0.01	0.63	0.29	5.40	0.00	g
Total Fluoranthene	µg/l	0.01	<0.01	1.02	0.30	12.50	0.01	g
Total Pyrene	µg/l	0.01	<0.01	1.03	0.31	12.50	0.01	g
Total PAHs (Total)	µg/l	0.01	<0.01	7.52	3.33	62.18	0.04	g

LOD = Analytical limit of detection

Maintenance Projects

3.8 A broad range of potential pollutants are also associated with maintenance projects which may range from routine cleaning of gully pots and similar entrapment structures to carriageway maintenance work. The flushing-out of gully pots has been identified as a potential source of pollutants, which may be as damaging as some spillage impacts. The use of herbicides for the control of plant growth along road verges and central reservations may also lead to contamination of road runoff.

Ecological Impacts

3.9 Potential pollution effects can be classified into two groups; those which directly and indirectly affect water quality, and those which affect the aquatic habitat quality. In broad terms, the former are metals which chemically impair biological functions and the latter are sediments which smother feeding and breeding grounds (especially for trout and salmon) and physically alter the habitat.

3.10 Depending on the type and form of the pollutant and its concentration and uptake by the organisms, the potential impact of the chemical pollutants can be either acute or chronic in nature.

3.11 Acute effects are usually associated with certain metals and organic pollutants. Copper in a soluble form is particularly toxic and there are standards for concentrations in respect of general quality and sensitivity to fish. The more soluble or short chained organic pollutants such as herbicides may also cause acute effects.

3.12 Collaborative research has been undertaken by the UK HA and UK EA to investigate the acute (short-term) effects of soluble pollutants on the ecology of receiving waters. Using relevant toxicity data from tests on a range of aquatic organisms the results have been used to develop Runoff Specific Thresholds (RSTs) to protect receiving organisms from short-term exposure (six hours and 24 hours) to those significant pollutants identified in highway runoff (Table 3.1). The RST 24 hour is designed to protect against worst case conditions whereas the RST 6 hour is designed to protect against more typical exposure conditions of aquatic organisms to soluble pollutants in highway runoff. For zinc, water hardness was found to have a significant effect on short-term toxicity such that toxicity values decreased with increasing water hardness. For cadmium and copper, water hardness was not found to have a significant effect on short-term toxicity.

3.13 Data from short-term toxicity tests carried out by Kings College London on a range of 13 algal, invertebrate and fish species along with literature data for other relevant species were used in the development of the RSTs. The species used in the RST derivation were largely UK resident species and included those with a range of sensitivities to the significant pollutants. The same taxonomic group proved not to be the most sensitive for all the pollutants of interest. In generating the RSTs a further assessment (safety) factor was applied to the no-effects threshold from the dataset to account for any possible effects on potentially more sensitive species that were not tested during the research. In this way the RSTs are protective against possible short-term effects on tested and untested (sensitive) species. The approach used to generate the RSTs is consistent with that adopted for the derivation of EQSs under the WFD.

3.14 The RSTs are designed to be used alongside relevant WFD EQSs for soluble pollutants which are designed to protect against long-term exposure. Table 3.2 summarises the RSTs developed from the UK study. The RSTs have been agreed with the UK EA and incorporated within the assessment tools and guidance discussed further in Chapter 5.

Table 3.2: RST s for short-term exposure (WRc 2007)

		Zinc (µg/l)		
		Hardness		
Threshold Name	**Copper (µg/l)**	**Low (<50mg CaCO 3/l)**	**Medium (50 to 200mg CaCO 3/l)**	**High (>200mg CaCO 3/l)**
RST 24 hour	21	60	92	385
RST 6 hour	42	120	184	770

3.15 Chronic effects are associated with sparingly soluble metals such as zinc, chromium, nickel and lead, where there is toxicity through accumulation of the metals in animal tissue. More persistent hydrocarbons such as PAHs are also considered as constituents of the sediment-bound fraction.

3.16 The physical accumulation of sediment (silt and clays) can alter habitats by covering surfaces as well as smothering flora and fauna. Where the sediment is contaminated with metals and PAHs, chronic effects can develop over time as a result of the leaching of the toxins from sediments or can directly affect sediment dwelling organisms.

3.17 Collaborative research has been undertaken by the UK HA and UK EA to investigate the chronic effects of sediment-bound pollutants on the ecology of receiving waters. This research identifies the scenarios under which contaminated sediment in runoff would be likely to have a negative impact on receiving water ecology. The results have been used to develop Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) for metal and PAH concentrations in sediment. The TEL is the concentration below which toxic effects are extremely rare. The PEL is the concentration above which toxic effects are observed on most occasions. Table 3.3 summarises the TELs and PELs derived from the study. In the absence of nationally agreed sediment guideline standards, the TELs and PELs have been agreed with the UK EA as a pragmatic approach reflecting current best practice. They have been incorporated within the assessment tools discussed within Chapter 5 and will be reviewed regularly and amended as necessary to reflect changing legislation or regulatory requirements.

Table 3.3: TELs and PELs for Metal and PAH Concentrations in Sediment (Gaskell *et al.* 2008)

Sediment-bound Pollutant	Units	TEL	PEL
Copper	mg/kg	35.7	197
Zinc	mg/kg	123	315
Cadmium	mg/kg	0.6	3.5
Total PAH	µg/kg	1,684	16,770
Pyrene	µg/kg	53	875
Fluoranthene	µg/kg	111	2,355

Influencing Factors

3.18 There are a number of factors which influence both the pollutant concentrations in routine runoff and whether the runoff is likely to have an impact on the receiving water body. These factors are outlined below.

3.19 Collaborative research between the UK HA and UK EA identified factors related to site and rainfall event characteristics that influence the pollutant concentrations in routine runoff. Site characteristics found to have some significant influence on copper and zinc concentrations were Annual Average Daily Traffic (AADT) Flows and climatic region. Influential event characteristics were: month of rainfall event, maximum hourly rainfall intensity and antecedent dry weather period. These influencing factors have been incorporated within the assessment tool described further in Chapter 5. Other factors that were investigated but not found to have a significant influence on pollutant concentrations were total event rainfall and mean event rainfall intensity.

3.20 The potential impact of pollutants on the ecology of surface waters is also dependent on the characteristics of the receiving waters, particularly its water quality, hardness, flow rate and flow velocity. For example, watercourses having low flow rates have less potential for diluting road runoff and are more vulnerable than those with high flow rates. Similarly, where soft water is encountered metals are more toxic. Where flow velocities are low or even zero (such as lakes and canals) there is an increased risk from sedimentation around the point of discharge.

3.21 The risk of groundwater pollution is affected by the mineralogy of the soil or rock, the depth of the unsaturated zone and the nature of the pathways between the point of discharge and the receiving groundwater, as further described in Chapter 5. In general terms groundwater is less susceptible to pollution by particulates, but remains at risk from soluble contaminants.

Spillages

3.22 On all roads, there is a risk that a spillage or vehicle fire may lead to an acute pollution incident. It is generally accepted that the risk on any road is proportionate to the risk of a Heavy Goods Vehicle (HGV) road traffic collision. As new or improved roads are designed to reduce the collision rate, they will also lead to fewer acute pollution impacts. Where spillages do reach a surface watercourse the pollution impact can be severe, but is usually of short duration, typical of an acute pollution impact. If groundwater is polluted the impact can be long lasting and difficult, if not impossible, to remediate.

3.23 Goods transported as road freight and which pose a risk to people are covered by European Communities (Carriage of Dangerous Goods by Road and Use of Transportable Pressure Equipment) Regulations 2011 and European Communities (Carriage of Dangerous Goods by Road and Use of Transportable Pressure Equipment) (Amendment) Regulations 2013. These regulations allow rapid identification of the materials present and provide guidance on how to handle those materials safely. Many materials, however, which are not classified under this system, may cause significant pollution to water bodies. Such substances include milk/cream, fruit juices, alcoholic beverages, organic sludges and detergents.

3.24 There is little available data on the acute pollution impacts resulting from construction of road projects. Potentially, the main causes are likely to be due to spillages/leaks of fuels/oils or waste materials from runoff from the site, and or dewatering activities. CIRIA 648 and UK documents Pollution Prevention Guidelines 21 and 22 provide further advice on identifying and managing the risks.

3.25 Although acute groundwater pollution from roads is a relatively rare event, the consequences of spillage of highly mobile pollutants such as fuel or pesticides on groundwater are potentially the most severe form of pollution. Halting the spread of such pollutants, and remediation of the affected groundwaters can both be extremely difficult.

Possible Flooding Risks and Impacts to Local Drainage

3.26 The construction or alteration of a bridge or culvert can change the hydraulic charactersitics of a watercourse. This may result in:

a) An increase in flood levels upstream of the bridge/culvert due to the restriction in the watercourse;

b) An increase in flood levels downstream of the bridge/culvert due to the removal of a benefical restriction in the watercourse;

c) Erosion of or deposition of material in the watercourse or floodplain as a result of changes to the velocity in the watercourse due to a restriction;

d) Blockages of overland flow paths.

3.27 Consent is required under Section 50 of the Arterial Drainage Act 1945 for construction or alteration works on bridges and culverts. The design of these should be such that flood risks upstream and downstream are not increased. If there are no other viable options an acceptable afflux at the crossing may be agreed with the OPW provided it complies with any flood risk management objectives and plans for the area. Refer to www.opw.ie/en/floodriskmanagement/ for information regarding flood risk and construction or alteration of watercourse infrastructure. Refer to www.floodmaps.ie and www.cfram.ie/pfra for information regarding flood risk.

3.28 Section 9 of the Arterial Drainage (Amendment) Act, 1995 requires consent for modifications or relocations of 'relevant works' which means a watercourse, embankment or other works that has or have been completed pursuant to a drainage scheme. Section 47 requires consent for erection or alteration of weirs.

3.29 Construction in floodplains can affect the nature and extent of the flood envelope in the area of construction and for some distance upstream and downstream. This could have a serious impact on property owners within or near the floodplain, who may become exposed to a new or increased risk of flooding. Bridges and embankments, in particular, can obstruct or change the path of floodwaters, thereby changing the shape and/or extent of the flood envelope. A change in upstream flood levels, resulting from such an obstruction, is known as afflux. In Appendix A (Method F, Hydraulic Assessment), guidance is provided in assessing the afflux using the appropriate methodology and providing suitable mitigation.

3.30 A road built across a major floodplain can have a significant effect on flood levels, whereas one built alongside will be less. Providing compensatory flood storage can significantly mitigate the effect of the project on the maximum flood level. The effect on floodwater levels in any area of floodplain caused by any one element of road construction may be small. However, using the precautionary principle, the consequence of developing the whole floodplain (through both road construction and unrelated projects) could lead to a significant cumulative loss of floodplain storage. Therefore storage may be required as failure to do this would lead to a higher risk of flooding to properties within the catchment.

3.31 New roads or improvements should only be located within floodplains in accordance with The Planning System and Flood Risk Management guidelines.

3.32 Other sources of flooding should also be considered. Groundwater flooding, caused by higher than normal groundwater levels, can flood roads, making their use hazardous, and severely compromise the structural integrity of the pavement.

3.33 Flooding caused by surface water runoff in an undrained area or across a saturated, frozen or impermeable surface, sometimes referred to as 'pluvial' flooding, may also flood a road surface. This type of event is usually associated with high intensity rainfall (>30 mm/hr) and can result in overland flow and ponding in local depressions. Drainage systems may be overwhelmed, preventing runoff through the usual routes.

3.34 Discharges to ground should also be considered as a possible source of flooding. Infiltration of road runoff may surcharge local groundwater and cause a local rise in the water table. The material may not have sufficient permeability to allow water to infiltrate. This may lead to localised or down gradient flooding. The topography of the discharge site, the thickness and permeability of the unsaturated zone, the nature of the receiving aquifer, the groundwater level and the design of the discharge system may all affect the susceptibility of a site to groundwater flooding. The potential waterlogging of ground in the vicinity of discharge systems should also be considered. This will not be considered in the risk assessment presented in Appendix A, Method C and should be assessed by the Designer before discharge to ground is considered.

3.35 The OPW and local authority should be consulted as early as possible where proposed projects may have an impact on a floodplain or local drainage and the parameters for the assessment established. They may be able to make available additional data, such as the results of local studies carried out for other purposes and locations where flooding has been recorded. Agreement should be sought, where possible, on the type and scope of investigations of flood behaviour, and the parameters to apply in judging the acceptability of the results to the investigations undertaken. Additional flood risk information is also available upon request from the NRA. This includes GeoPDF interactive flood risk maps covering the entire national road network.

3.36 Even where roads are not within floodplains, their construction can cause local changes to catchment drainage patterns. The amount of runoff will increase as a greater area is paved, and without attenuation, there will be an increase in the rate at which runoff reaches the receiving water bodies. The increase from one drainage outfall alone may not make a significant difference to the water body, but the cumulative effect of all the outfalls in a road project, or the effects of its construction, may affect flood risk elsewhere in the catchment. Designers should satisfy the OPW and local authority that there is no increase in flood risk, and should be prepared to demonstrate this as part of their design. Refer to the OPW guidelines (www.opw.ie/en/floodriskmanagement/) for further information.

3.37 The construction of a new road forms a barrier that may cross existing drainage routes, causing potential blockage and altering local catchment areas and boundaries. It is usual practice to keep the existing land drainage separate from the road drainage where possible, using ditches and culverts beneath the road embankment. Where there are existing culverts within a length of road to be upgraded, their capacity should always be checked, even if there is no requirement for the culvert to be amended as a result of the project. This is particularly important if flooding upstream is a known problem. It is possible that there may have been changes to the upstream catchment since the culvert was built, resulting in the culvert's capacity being inadequate. NRA HD 106 Drainage of Runoff from Natural Catchments considers the effect of runoff from existing land drainage on road drainage, and NRA HD 107 Design of Outfall and Culvert Details considers the design of culverts and outfalls.

3.38 The construction of the road, its sub-surface drainage and its foundations (for example, deep structures associated with bridges) may also intercept groundwater flow, particularly where roads are in tunnels or cuttings. Interception of groundwater flow, if not appropriately drained, may also cause waterlogging or groundwater flooding up gradient. These impacts may be especially important where shallow groundwater systems support low flow in streams or where they feed wetlands. Any such impacts should be considered in project design and the OPW and EPA consulted with respect to the mitigation approach adopted.

3.39 In many locations, embanked flood defences and other structures such as weirs contribute to flood protection for areas at risk. It is necessary to ensure the integrity of such defences for the future, with suitable access preserved for inspection and maintenance of the defence. The OPW and local authority should be consulted to advise of the presence of any defences, and how they should be considered in a project design.

3.40 The methods of construction can also increase flood risk:

a) temporary paved surfaces or roofed areas of site compounds may increase the rate of runoff;

b) any works within the floodplain are likely to affect the local hydrology;

c) ditch or drainage diversions may affect catchment characteristics;

d) temporary bunding or material stockpiles may alter runoff from upstream areas; and

e) large areas stripped of vegetation can discharge runoff at a much higher rate than if grassed, and some provision for temporary storage of surface water may be needed.

Other Possible Impacts

3.41 A new or improved road may impact on the amenity value of a watercourse. Where a river, reservoir or canal is used for leisure activities, such as fishing or boating, these may be affected by the project. The project may interfere with (or improve) the access to the facility or the enjoyment of the activity. A consequential impact of the project may be economic, if, for example, a business on the waterfront is affected due to the impact of the project on the watercourse.

Project Objectives

3.42 It is important for projects to set project design objectives. These may be based on legal compliances or the NRA's policy objectives or they may be constructed to deliver particular local requirements for projects. In undertaking an assessment of the impacts and effects, designers need to be aware of these and understand that the assessment process should support the delivery of such objectives.

4. CLIMATE CHANGE

4.1 Climate refers to *'the average weather experienced over a long period, typically 30 years'* (United Kingdom Climate Impacts Programme). Climate includes wind and rainfall patterns alongside temperature. Over the past centuries the climate of the earth has changed many times in response to a variety of natural causes and is by definition not static. The term 'climate change' usually refers to recent changes in climate that have been observed since the early 1900s.

4.2 NRA HD 33 Drainage Systems for National Roads stipulates the requirements for the incorporation of climate change in rainfall calculations that shall be incorporated in the drainage design for National Roads projects.

4.3 Refer to http://www.opw.ie/en/floodriskmanagement/ and www.cfram.ie/pfra for further information on climate change.

Effects of Climate Change

4.4 The trends in precipitation changes are only recently becoming clearer. Research normally splits the patterns in to changes of averages and changes in extremes. Increased rainfall in the autumn and winter months and an increase in peak rainfall intensity and frequency of events are expected for Ireland.

a) Autumn and winter seasons will become wetter: increases in the range 15-25% towards the end of the century (Ireland in a Warmer World).

b) Winter values typically show increases of 0-8% (medium-low emissions) rising to mostly between 4 and 14% for high emissions (GDSDS).

c) The frequency of heavy precipitation events during winter shows notable increases of up to 20% (GDSDS).

4.5 While a reduction in summer rainfall is expected, the intensity of this rainfall is projected to increase by some so we can expect less frequent but more intense rainfall events.

a) Summers will become drier: 10-18% decrease towards the end of the century (Ireland in a Warmer World).

b) In the summers, the reductions are typically 4-16% (medium-low emissions) and up to 20% for high emissions. Spring is also drier (0-8%) (GDSDS).

4.6 The increased intensity and frequency of the rain events will necessitate drains to be capable of transmitting a larger peak flow rate. It is also logical to assume groundwater levels will be affected with higher variability in range of levels observed, that is extreme low levels in summer and extreme highs in winter. The increase in drought events may lead to longer dry periods with the residual flow in the drains falling to lower levels. Increased evaporation could also impact on loading of drainage networks.

4.7 The Irish climate Analysis and Research Units investigated the impact the range of climate change scenarios had on 4 catchments, the Blackwater, the Boyne, the Moy and the Suck. The results are summarised in Table 4.1. This table summarises simulation results for, median, lower 5% and upper 95% value of the flood quintiles for the three future time periods. Changes are calculated based on the corresponding flood frequency curve estimated for the present climate.

Table 4.1: Summary of Future Flood Simulation Results

Period	Change from baseline/change to future	Return period (Year)			
		5 (% increase)	**25 (% increase)**	**50 (% increase)**	**100 (% increase)**
2020s	Lower 5%	4.3-10.8	5.5-10.2	5.6-10.0	5.9-9.6
	Median	8.5-11.5	9.1-11.4	9.3-11.3	9.2-11.1
	Upper 95%	12.4-17.5	11.3-17.8	8.8-18.9	7.0-21.7
2050s	Lower 5%	7.9-14.3	10.1-14.7	10.7-15.0	11.6-14.8
	Median	11.1-17.5	13.3-18.0	13.6-18.5	14.8-18.6
	Upper 95%	19.7-28.5	18.4-31.7	15.3-34.4	11.9-39.8
2080s	Lower 5%	8.0-15.0	10.3-15.5	10.8-15.8	11.3-16.5
	Median	14.5-19.6	15.3-21.0	15.6-21.9	15.8-22.5
	Upper 95%	24.0-34.5	23.5-43.7	19.3-49.0	14.9-55.7

Coastal Effects

4.8 Climate change will impact both mean sea level and storm surge conditions. It is important to appropriately consider and account for the potential impact for tidally and coastally affected outlets.

4.9 The majority of sea level rise guidance recognise that mean sea level rise is occurring but the recommendations tend to be executed by different methods. These recommendations may include (i) a flat linear rate (e.g. 3mm/year), (ii) linear sea-level rise rates over period of time (e.g. UK FCDPAG3), or (iii) logarithmic rate of increase either as a curve (e.g. USACE) or a ‘stepped’ equivalent. At present, observed sea level rise around Ireland is approximately 3.5mm/year.

4.10 Ocean modelling results indicate an increase in the frequency of storm surge events around Irish coastal areas. There is also a significant increase in the height of extreme surges (in excess of 1 m) along the west coasts, with most of the extreme surges occurring in wintertime. Extreme wave heights (e.g. the 10-year return values) also show an increase - up to 10% around the northwest coast.

Future developments

4.11 Many climate change scenario models rely on input from the Intergovernmental Panel on Climate Change (IPCC), whose most recent Assessment report, AR5, was published in 2014.

5. PROCEDURE FOR ASSESSING IMPACTS

General

5.1 The general procedure for assessing impacts on the water environment as part of any environmental assessment process follows the principles as set out in the following:

a) EPA Guidelines on the Information to be Contained in Environmental Impact Statements;

b) EPA Advice Notes on Current Practice;

c) NRA Project Management Guidelines;

d) NRA Environmental Impact Assessment of National Road Schemes – A Practical Guide;

e) NRA Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology.

5.2 The first step in the process will be to scope any assessment. For scoping criteria refer to paragraph 6.8 and the documents listed in paragraph 5.1. Where this exercise concludes that assessment is warranted the methods set out below must be used.

5.3 This chapter describes the procedures that must be used when assessing the potential impacts from road projects on the water environment. Methods are described in Appendix A for the following topic areas:

a) Methods A and B – Effects of Routine Runoff on Surface Waters;

b) Method C – Groundwater Protection Response (GPR) for the use of permeable drain systems on Road Schemes;

c) Method D – Pollution Impacts from Accidental Spillages;

d) Methods E and F – Assessing Flood Impacts.

5.4 Guidance is also provided on: assessing the potential for erosion during construction, identifying cumulative impacts, and gauging the significance of any potential environmental effects that are identified as part of the assessment process.

Effects of Routine Runoff on Surface Waters

5.5 UK Research has shown that pollution impacts from routine runoff on receiving waters appear to be broadly correlated with Annual Average Daily Traffic (AADT). The site with the lowest traffic flow which was studied during the research had an AADT of 11,000. The traffic flow below which potential pollution impacts are insignificant is not clear. Many National Roads in Ireland carry less than 10,000 AADT. On such lightly trafficked roads, pollutants will occur in lower concentrations but an assessment of the potential impacts shall be made using the lowest traffic flow input for Methods described in Appendix A. Where discharges from these lightly trafficked roads feed into sensitive water bodies (such as Special Protection Areas (SPAs) and Special Area of Conservation (SACs)) an assessment of the potential impacts should be made using the normal methods described in the following paragraphs.

5.6 An assessment of the potential ecological impacts of routine runoff on surface waters is required in order to determine whether there is an environmental risk and if pollution mitigation measures are needed in specific circumstances. The Highways Agency Water Risk Assessment Tool (HAWRAT) has been developed for this purpose and the methodology behind it has been derived from a collaborative research programme undertaken by the UK Highways Agency (HA) and UK Environment Agency (EA) which investigated the effects of routine road runoff on receiving waters and their ecology. The toxicity thresholds determined through the research programme, and which are used by the tool, have been designed to prevent adverse ecological effects in the receiving water. Equally, in artificial and heavily modified water bodies, the thresholds have been designed to prevent adverse effects on ecological potential. The thresholds are consistent with the requirements of the WFD and the use of the tool, for assessment of potential impacts of routine runoff on surface waters, is appropriate for National Road Schemes in Ireland. As the WFD aims to achieve 'good' ecological status in all water bodies, it is not appropriate to allow existing water quality to influence the outcome of the assessment. The ecological status of the receiving water are, therefore, not considered by HAWRAT, rather, the tool applies the same toxicity thresholds to all assessments regardless of receiving water quality. The EPA have acknowledged the method of assessment used by HAWRAT and it's use within the Environmental Impact Assessments (EIA). The tool's design is also consistent with the consequential levels of assessment approach described in Chapter 6 and requires relatively little site-specific data to make an assessment.

5.7 HAWRAT is a Microsoft Excel application which can be downloaded from the Highways Agency Drainage Data Management System (HADDMS) www.haddms.com. HAWRAT may be upgraded periodically and users should check that the most up-to-date version is being used.

5.8 The principal features of HAWRAT are outlined below. An explanation of how to use the tool is given in Appendix A and worked examples are given in Appendix C. For a full description of the tool refer to the associated Help Guide and Technical Manual.

5.9 The following pollutants have been incorporated within the assessment process (and HAWRAT):

a) soluble pollutants associated with acute pollution impacts, expressed as Even Mean Concentrations (EMCs) for dissolved copper and zinc;

b) sediment-bound pollutants associated with chronic pollution impacts, expressed as Event Mean Sediment Concentrations (EMSCs) for total copper, zinc, cadmium, pyrene, fluoranthene, anthracene, phenanthrene and total polycyclic aromatic hydrocarbons (PAH).

5.10 As shown in Table 5.1, HAWRAT adopts a tiered consequential approach to assessment and can report the results at three different stages depending upon the level of assessment required for any given site. These are:

a) Step 1, the runoff quality (prior to any pre-treatment and discharge into a water body);

b) Step 2, in river impacts (after dilution and dispersion);

c) Step 3, in river impacts post-mitigation.

5.11 At Step 1, HAWRAT predicts the statistical distribution of key pollutant concentrations in untreated and undiluted road runoff (the 'worst case' scenario) over a long release period. The distribution uses a statistical model, developed through research, which is based on a ten year rainfall series relevant for the chosen site and its climatic region. The results are assessed on a pass/fail basis against the toxicity thresholds described in paragraphs 3.12 and 3.17. These represent a guideline emission standard in the absence of any pre-treatment within the drainage system or in-river dilution and dispersion.

5.12 At Step 2 the assessment becomes more realistic and is only applied if one or both the toxicity thresholds are predicted to fail at Step 1. HAWRAT uses details of the road catchment draining to the outfall, the flow rate of the receiving watercourse and its physical dimensions to calculate the available dilution of soluble pollutants and potential dispersion of sediments. A further comparison with the pollutant thresholds is then made. For the soluble pollutants that cause acute impact this involves a simple mass balance approach. For the sediment-bound pollutants that cause chronic impact, the ability of the receiving watercourse to disperse sediments is considered and, if sediment is expected to accumulate, the potential extent of sediment coverage (the deposition index) is also considered. Additionally, Step 2 contains two tiers of assessment for sediment accumulation: Tier 1 is a simple assessment requiring only an estimate of the river width. If required, Tier 2 is a more detailed assessment which requires a site visit to measure the physical dimensions of the river. If a Tier 1 assessment indicates no risk then unnecessary work for a Tier 2 assessment is avoided. Appendix D contains a field log sheet designed to assist in site visits.

5.13 The pollution risk estimated at Steps 1 and 2 assumes the drainage system includes no pollution control measures to mitigate the risk. Where this risk is considered unacceptable, pollution control can be included at Step 3 in order to assess either the effectiveness of existing measures or the required scale of any proposed new measures (including retained existing measures). It should be noted that Sustainable Drainage Systems (SuDS) should be considered in the first instance over conventional drainage systems, as per NRA HD 33, and the need for SuDS cannot necessarily be ruled out if the tool indicates that the discharge will pass at Steps 1 or 2.

5.14 As shown in Table 5.1, the HAWRAT tool uses a pass/fail reporting method whereby:

a) ‘Fail’ indicates either; an unacceptable impact, a need to carry out further assessment steps, or a need to refer the situation to specialist judgement;

b) ‘Pass’ indicates that there will be no short-term impact associated with road runoff (long-term impact should be assessed separately).

Table 5.1: Stages of Assessment in HAWRAT

Stage of Assessment	**Inputs**	**Outputs**
Step 1 Runoff Quality	• Traffic volume • Geographic location • 10 years of rainfall data, ~1000 rainfall events (embedded in HAWRAT)	• Runoff concentrations of soluble pollutants and sediment-bound pollutants for each event • Pass/Fail standards
Step 2 in River	• Outputs from Step 1 • Area draining to outfall • Characteristics of receiving watercourse	• Concentration of soluble pollutants after dilution • Stream velocity at low flow • Deposition index (extent of sediment coverage) • Pass/Fail standards • Percentage settlement required to comply with deposition index • Annual average concentrations of soluble pollutants

Stage of Assessment	Inputs	Outputs
Step 3 After Mitigation	• Outputs from Steps 1 and 2 • Existing and proposed mitigation measures • Treatment of soluble pollutants or flow attenuation • Settlement of sediments	• Concentration of soluble pollutants after treatment • Concentration of soluble pollutants after further dilution • Pass/Fail standards • Annual average concentrations of soluble pollutants after mitigation

5.15 If HAWRAT indicates low risk, there is a high level of confidence that there will be minimal short-term impact. The methodology uses tighter pollutant thresholds for more sensitive watercourses such as SPAs and SACs.

5.16 HAWRAT is designed to make an assessment of the short-term risks to receiving-water ecology which relate to the intermittent nature of road runoff. An assessment of the long-term risks (using annual average concentrations) is also required to complete the risk assessment process. HAWRAT estimates in-river annual average concentrations for soluble pollutants (dissolved copper and dissolved zinc) which include the contribution from road runoff. These concentrations can be compared with published EQSs to assess whether there is likely to be a long-term impact on ecology. The procedure for long-term assessment is discussed in more detail in Appendix A, Methods A and B.

5.17 When the potential for both short-term and long-term impacts have been assessed there will be a number of possible outcomes. These are listed in Table 5.2 together with the actions that will need to be taken in each scenario.

Table 5.2: Assessment Outcomes and Actions to Take

HAWRAT Assessment[1]	Assessment against EQSs[2]	Action
Pass	Pass	No further action
Fail	Pass	i) Factor in effects of proposed design and reassess ii) Consider implications of redesign and reassess iii) Weigh up benefits over whole scheme iv) Agree action (may require continued monitoring)
Pass	Fail	i) Check sensitivity of modelling to input parameters e.g. Q_{95} ii) Determine appropriate mitigation
Fail	Fail	Redesign

[1]To Pass the HAWRAT assessment requires both solubles and sediments to pass. If either fail, then use fail in this table.

[2]To Pass the EQS assessment requires both dissolved zinc and dissolved copper to pass. If either fail, then use fail in this table.

5.18 The risks to each receiving watercourse should be assessed for each individual discharge. Where outfalls discharge to the same watercourse or river reach, the combined risk should be assessed according to the principles given in Appendix A. HAWRAT is not specifically designed to assess any proposed discharges to lakes although the tool does require the form of the receiving water to be considered. Lakes within 100 m downstream of the outfall (along the river) are assumed to accumulate road derived sediments and the tool will identify this as an unacceptable risk.

5.19 Discharges must not be made into lakes, ponds or canals. If a proposed discharge into a lake, pond or canal is unavoidable the methods adopted in the assessment of any potential impacts should be agreed with the EPA, IFI, OPW, NPWS and the local authority as appropriate.

5.20 A key input parameter for HAWRAT is the flow rate of the river under low flow conditions when exceedances of the ecological thresholds are more likely. This parameter is used by the tool to calculate both dilution of soluble pollutants and the river velocity which, in turn, is used to estimate whether sediment is likely to accumulate. The usual low flow parameter is the Q_{95}, which is defined as the flow equalled or exceeded in a watercourse 95% of the time. Q_{95} is not as commonly reported as flood flows, though data are available from major gauging stations and these are the most reliable figures to use. A list of these flows for gauging stations is available from http://www.epa.ie/water/wm/hydrometrics/data/. These values are actual Q_{95} flows and include the effects of any artificial influences, such as abstractions or discharges. It may be possible to use data from a catchment with similar characteristics.

5.21 Watercourse flows in Ireland can be affected by artificial influences: either abstractions, discharges or both, such that actual Q_{95} flows usually differ from natural Q_{95} flows. Natural flows can be estimated using the Low- Flow prediction for ungauged river catchments in the Ireland guidance. This can be used to give a first order estimate of the natural Q_{95} flow. Where artificial influences are known to exist a further allowance will have to be made to any estimated value of the natural Q_{95} flow to enable the actual Q_{95} flow to be derived. Where there is any doubt over the Q_{95} used, the EPA and IFI should be consulted.

5.22 HAWRAT has adopted within its design a precautionary approach. It produces a conservative estimate of the potential impact of water quality downstream of a discharge. One advantage of this approach is that it readily differentiates between low risk sites requiring no further assessment or mitigation and those sites that may require further detailed assessment and/or mitigation. This allows earlier identification of potential polluting sites and more effective use of resources. Specific assumptions within HAWRAT include:

a) Tier 1 map-based estimation of river width. A regression equation is used to calculate the cross-sectional area of the river from the river width. The area is then used for calculation of river velocity and depositional index. The stream dimensions used to generate this equation represent a small subset of the potential full range of conditions. As a precaution the upper 95% confidence interval of the regression equation is applied. Therefore, in most cases the stream velocity will be underestimated and the depositional index overestimated. Tier 1 is provided as a simple and conservative check, which, if no risk is identified, will save further work being carried out. More accurate assessment for Tier 2 requires a site visit for the river dimensions to be measured.

b) In situations where road derived sediment is likely to accumulate the extent of deposition is assessed against a dimensionless deposition index value of 100. UK research and subsequent validation was not able to provide detailed information on the extent of sediment deposition that is likely to have an ecological impact. A starting value of 100 should be used. This value is considered conservative.

c) HAWRAT assumes that the road pavement represents an infinite source of sediment, which may lead to an overestimate of the extent of deposition. Sediment exhaustion is likely to be a factor of the antecedent dry weather period and the duration and intensity of the rainfall. There are currently no data available from which to establish a sediment exhaustion factor.

d) Sediment arriving in the river when the velocity is less than 0.1 m/s is assumed to accumulate, the rest is assumed to disperse. The deposition index is a consideration of the extent of sediment coverage. It is likely that when velocities are higher, part of the accumulated sediment will be removed. However, the tool is not able to incorporate this removal mechanism and all accumulating sediment is considered to remain and add to the annual total.

e) The estimated river flow for a given rainfall event will be generated by the model at the start of the event, i.e. it will not be influenced by the event itself. This is a conservative approach and recognises that the road runoff response will generally be much faster than the river flow response. However, if there is any increase in the river flow rate and flow velocity there will be greater dilution and an increased chance of reaching the dispersing velocity threshold of 0.1 m/s. This is thought to be especially significant in smaller streams where road runoff can represent a significant part of the flow and increase velocities considerably.

5.23 HAWRAT provides a safe means of identifying those proposed discharges which will not adversely affect receiving water quality with respect to soluble and sediment-bound pollutants.

5.24 HAWRAT was developed primarily for use on non-urban trunk roads and motorways in England and has been adapted to reflect conditions within Wales, Scotland and Northern Ireland. It is appropriate for use on National Roads in Ireland as the rainfall and climate characteristics etc are similar. Care should be taken when considering its use in the following situations and, where appropriate, advice should be obtained from EPA, IFI, OPW and NPWS, and approval obtained from the NRA:

a) urban roads (where a wider range of pollutants and larger concentrations might arise which may be under-represented by HAWRAT because of the reference datasets);

b) roads where the receiving water course is tidal.

Effects of Routine Runoff on Groundwater

5.25 For discharges to groundwater, an assessment procedure has been developed in consultation with the EPA and GSI through the production of a development specific Groundwater Protection Response (GPR). This methodology is included in Appendix A (Method C, Groundwater Protection Response for the use of Permeable Drainage systems on road schemes). The following section outlines a summary of the procedure and highlights key points in relation to its implementation.

5.26 For the purposes of this assessment a permeable system is one which allows surface water runoff to enter groundwater. Table 5.3 presents examples of systems which may be considered as permeable. Refer to NRA HD 33 for a list of permitted drainage systems.

Table 5.3: Example of permeable and impermeable systems

Permeable systems	Impermeable systems
• Over-the-edge Drainage	• Kerb & Gully
• Combined Filter drains	• Concrete Surface Water Channel
• Grassed Surface Water Channels	• Linear drainage channel
• Swales/ditches	• Combined kerb and drainage block
• Infiltration basins/trenches	
• Soakways	

5.27 The GPR is based on the vulnerability of the groundwater and the aquifer classification. The presence of Source Protection Areas for public supply wells are also considered. The vulnerability assessment should be completed based on site specific data for the ground and should consider the material beneath the proposed invert level of the drain and should not be based on existing ground levels. It should specifically consider the site specific material properties and these will over-ride generic assessment criteria. It should be noted that the vulnerability should be classified based on the depth to the protected aquifer and not the shallowest water strike.

5.28 The aquifer classifications for any area can be obtained from the GSI. It should be noted that gravel and bedrock have different criteria to be applied to allow the aquifer classification to be defined.

5.29 The assessment methodology should be considered as a screening tool and be undertaken at the design (Phase 3 of the NRA PMG) and environmental assessment (Phase 4 of the NRA PMG) phases of a project based on the information available at that time. Sufficient information should be available during Phase 3 and 4 to carry out these assessments. The assessment should then be refined during Phases 5 and 6 (NRA PMG) if further information becomes available. Where relevant, a site specific risk assessment undertaken by qualified groundwater professional may superceed the requirements of the GPR. In these cases the assessment methodology followed should be fully outlined, the raw data provided and any interpretation of the data should be clearly explained.

5.30 If the assessment is undertaken and determines that permeable drainage is not suitable, mitigation measures can be designed and incorporated into the proposed design. The GPR assessment should be undertaken again at this stage, this time considering the proposed mitigation measures. The stages of the assessment, including any iterations of the assessment to include mitigation measures, should be fully documented.

5.31 Sufficient data should be collected at Phases 3 and 4 to ensure that the assessment can be completed. This data should include information on the winter groundwater levels, site specific geological strata, the properties of the material including permeability and particle sizes. Specialist input by a hydrogeologist should be sought at an early stage of the ground investigation to ensure that the information collected is suitable including for example response zone design.

5.32 A number of practical considerations have been identified which should be assessed prior to following the GPR methodology. These including the potential for karst reactivation, groundwater flooding etc. If these are identified as risks then discharges to ground should not be considered and an impermeable drainage system should be designed or a site specific assessment of the impacts to groundwater should be undertaken.

Pollution impacts from spillages

5.33 Spillages caused by accident or other causes can occur anywhere on the road network. Although the effect of many road projects will be to reduce the overall risks of collisions, it is important to assess the risks of an acute pollution impact.

5.34 Method D in Appendix A contains a step-by-step guide to the calculation of these risks. HAWRAT also includes a facility to assess spillage risk using the same method. The method initially estimates the risk that there will be a collision involving the spillage of a potentially polluting substance somewhere on the length of road being assessed. It then calculates the risk, assuming a spillage has occurred, that the pollutant will reach and impact on the receiving watercourse.

5.35 It should be noted that the Groundwater Protection Response (Method C) presented in Appendix A does not deal with discharges to ground from spillages and only considers routine run-off.

5.36 Spillage risks can conveniently be expressed as annual probabilities of such an event occurring. This allows objective decisions to be made as to their acceptability, or whether measures are needed to reduce the risk. The risks to each receiving water body should be assessed. Where more than one outfall discharges to the same water body, the combined risk from all such outfalls should be assessed. This is especially important if several outfalls discharge to the same reach of a river.

5.37 As a guide, water bodies should be protected so that the risk of a serious pollution incident has an annual probability of less than 1% (this is the same as the general probability standard to which properties should be protected against river flooding). In circumstances where an outfall discharges within close proximity to (i.e. within 1 km) a protected area for conservation (such as those listed in paragraph 2.13) or could affect important drinking water supplies or other important abstractions, a higher standard of protection will be required such that the risk of a serious pollution incident has an annual probability of less than 0.5%. The assessment methodology has been derived from an analysis of spillage incidents in England and Wales. This tool is applicable for spillage risk assessments on National Roads in Ireland also. In considering the risk of a spillage occurring, it has been assumed that they are distributed across the network in the same way as personal injury collisions involving Heavy Goods Vehicles (HGVs). The spillage rates given in Table A.5 in Appendix A are for motorways and for both rural and urban all purpose trunk roads. For the purposes of spillage risk assessments on National Road Schemes in Ireland, the term ‘trunk’ can be taken to mean ‘National Road’.

5.38 The rates given for junctions apply to the lengths of road within 100m of the centre of junctions. Occasionally, allowance will have to be made where it is known that a road carries an unusually high proportion of vehicles with hazardous loads.

5.39 The methodology gives a higher risk for more sensitive water bodies, and for those in remote locations. This recognises that where there is a prompt and effective response to a spillage, the risk of a pollution incident is significantly lower, and such responses are less likely in remote locations.

5.40 The pollution risk is initially estimated assuming the drainage system includes no measures to mitigate the risk. Where this risk is assessed to be in excess of the acceptable limit, some form of pollution control should be included to reduce the risk. Mitigation measures and their effect on pollution risks are discussed in Chapter 8 of this document.

Assessing Flood Impacts

5.41 A summary of the principal stages in the procedure for assessing potential flood impacts is given in Appendix A, Method E (Hydrological Assessment of Design Floods) and Method F (Hydraulic Assessment). The most important decisions in the planning stages are as follows:

a) to ensure that any route options which avoid floodplains are fully investigated;

b) outline bridge designs may require alteration to comply with afflux limits. The cost effectiveness of achieving this should be compared to other options such as providing separate flood relief culverts;

c) costs and benefits should be assessed when considering the need for compensatory flood storage, alternative measures to reduce floodwater levels or the protection of areas where the flood risk would otherwise be increased.

5.42 Other factors which may require more detailed assessment at the design stage are:

a) the hydraulic performance of bridge structures and culverts;

b) the effect of any works affecting rivers both upstream and downstream;

c) the impact of road runoff on river flows;

d) the effects of road construction on hydrological regimes and catchments;

e) consequential impacts on aquatic and other environments.

5.43 In the lowest reaches of some rivers, where water levels are mainly determined by tidal effects, it is probable that flooding may be caused by tidal water levels alone. The upstream limit of tidal flooding will be determined by river flows. There will also be an intermediate zone where flooding may be either fluvial, or tidal, or caused by a combination of the two.

5.44 In the intermediate flooding zone, it is important to select a design event that takes tides and river flows into account. Refer to www.opw.ie/en/floodriskmanagement/ for further information.

5.45 In tidal reaches where water levels are continually rising or falling, the time of the peak tide will vary along the river. A joint probability analysis should be carried out. Unsteady state hydrualic modelling will be required to determine the resultant impacts of coincident high tides and high flows. An estimate should also be made as to what is the likelihood of coincidence of these events.

5.46 The design flood event is as per OPW guidelines (refer to www.opw.ie/en/floodriskmanagement/). The return periods should be appropriate for river flooding, and not necessarily the same as those used for scour, forces on bridges, and other design considerations.

5.47 The OPW's Flood Studies Update (FSU) Web Portal facilitates the estimation of flood flows, extreme rainfall depths, and other hydrological variables, for thousands of river locations in Ireland and shall be consulted where practical for flood estimation (refer to www.opw.ie/en/fsu/). Hydological calcualtions should be carried out by an appropriately qualified and experienced practitioner.

5.48 The assessment procedure is intended to provide a first order estimate of the effects of the crossing on flooding. Where the effects on floodwater levels are significant, sensitivity tests should be carried out for floods across a range of annual probabilities and should take account of possible climate change impacts discussed in Chapter 4 of this document.

5.49 Refer to the OPW guidelines and section 50 guidelines (www.opw.ie/en/floodriskmanagement/) for the maximum allowable afflux. This should be carried out at an early stage in the planning procedure. The extent of environmental impact, changes in the flooding regime and any residual impacts should always be considered.

5.50 A range of design options should be assessed to ensure that the afflux value can be justified in terms of value for money.

5.51 Any construction within a river or estuarial floodplain will occupy areas which were previously available for flood storage or flows. Therefore, flood storage compensation may be required. For example, if an embankment is built within a floodplain, the OPW may request that material is removed in areas as close as possible to the proposed road crossing, so that the compensation works relate hydraulically to loss of floodplain. Works located remote from the infill site will not be acceptable, as these can change the natural hydrology of the catchment. The compensation storage should be designed to provide at least the same volume at every level as is occupied in the existing situation. The impact of the loss of floodplain storage should be calculated using Method F (Hydraulic Assessment) in Appendix A. Although in many cases the storage volume will be small for a single project, works should be carried out to avoid increasing flood risk by cumulative impact.

5.52 The provision of compensatory storage can have environmental impacts with regard to habitats. These impacts should be compared with the alternative impact of higher floodwater levels in the catchment. Consultation with the EPA, IFI, OPW and NPWS will be required when assessing these impacts.

Assessing Potential for Erosion During Construction

5.53 At the planning stage (Phase 3 and 4 of the NRA PMG), environmental assessments for construction projects should include an erosion prevention and sediment control plan.

5.54 The first aim of the erosion prevention and sediment control plan should be to minimise erosion by reducing disturbance and stabilising exposed materials. The plan should then consider control measures to minimise the release of mobilised sediment which results despite the erosion control measures. Measures to prevent erosion are more effective than controlling sediment once mobilised. Further advice on preparing an erosion and sediment control plan is provided in CIRIA 648. Further advice on pollution control during construction is provided in NRA Guidelines for the Crossing of Watercourses during the Construction of National Road Schemes. The potential risk from erosion and sediment control issues should be identified and reported in the Environmental Impact Statement (EIS) where construction impacts are considered. Ideally, and where necessary, a commitment would be made in the EIS to indicate the general strategy for erosion prevention and sediment control. This is sufficient at the planning stage, however, the detail of such plans should be worked up as part of the Environmental Operating Plan (EOP) after EIS publication.

Assessing Cumulative Impacts

5.55 Many environmental impacts are caused by the cumulative effects of one or more separate impacts. These may be due to the coincidence of impacts, or the cumulative impact of separate events occurring at different times. They may be impacts on one aspect, e.g. landscape, caused by works to mitigate the impact of the water environment.

5.56 In assessing the impacts to the water environment, it is necessary to consider how the impacts may affect the relevant catchment or river basin. The WFD requires the preparation of River Basin Management Plans (RBMPs) showing all significant impacts to the waters in a particular river basin. The interaction of new impacts from road works with existing impacts may well produce cumulative impacts. The EPA, IFI, OPW and NPWS should be consulted where it is considered such cumulative impacts are possible and a copy of the RBMP examined.

5.57 An example of a cumulative impact to a river basin is the situation where two or more streams in the same river basin are affected by the same project. This situation is likely to arise where a road runs parallel to a watercourse for more than a kilometre. In assessing the cumulative impact, consideration should be given to the possibility of an impact to the receiving river, as well as to the streams themselves, even if that river is remote from the site.

5.58 Where roads are being improved and include existing culverts, an assessment should be made of the culvert's capacity, even if it will not be affected by the project. Where in such circumstances it appears that the culvert is inadequate, the local authority, NRA and OPW should be consulted for advice on whether the capacity should be increased as part of the project.

5.59 In areas within the tidal floodplain, the cumulative impact of the possible combination of tidal and fluvial flooding should be considered. Furthermore, there is the possibility of the combined impact of either of the above forms of flooding with flooding caused by rising groundwater. The effect of flooding is usually most severe when heavy rain falls on ground that is already waterlogged, either from earlier rain or by high groundwater levels.

5.60 Where new construction within a floodplain is unavoidable, there may be a requirement for compensation to be provided elsewhere. The compensatory flood storage may well cause other environmental impacts, for example on the landscape or existing ecology, as well as the water environment, and these should be assessed along with the direct impacts of the project.

5.61 Temporary effects from the construction of a project may be cumulative. For example, spoil from an excavation could be washed into a river as a result of a severe rainfall or flood event. The risk of such a flooding event and the consequential damage to the water quality should be assessed, together with the risk of spoil being deposited in a flood prone location. Depending on the nature of the watercourse, small discharges of spoil could accumulate on the river bed, leading to a risk of ecological damage to any fish and their spawning areas. There can be a particular risk if the material washed into the river has been imported to the site, as its presence may cause a change to the chemical as well as physical quality of the water.

Assessing the Significance of Effects

5.62 It is not sufficient to assess the size and probability of possible impacts: their significance should also be assessed. For example, the impact of a large spill will be more significant if the stream it discharges to is a source of potable water, and a flood will be more significant if it affects a residential area. Where the risk of an impact is uncertain, as a result of a lack of information, this should be considered as part of the assessment.

5.63 Having identified the potential impacts, it will be possible to define the area within which the project is likely to have an influence. It can be useful to distinguish between impacts arising directly from a new or widened road, and those arising from changes to existing patterns in the use of an existing road, as a result of, say, a traffic management project. An assessment should be made of the importance of the water environment by considering the features within the study area. The environmental value of a feature such as a river is characterised by identifying and analysing its attributes, such as its use as a source of water, whether for potable or other use, its use for recreation, its function as a drainage channel or its value to the economy. The EPA, IFI, OPW and NPWS are likely to have a view on the importance of these features and should be consulted. Where the attributes have landscape, biodiversity, economic or cultural heritage value, impacts likely to affect those attributes should be considered in the parts of the assessment dealing with those environmental aspects.

5.64 The nature of likely impacts in terms of magnitude, quality, significance and duration shall be determined in accordance with the NRA's Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes. The importance of the attributes of water features that could be affected by the project should be recorded using a sheet, such as the one shown in Table B.1.

6. LEVELS OF ASSESSMENT OF IMPACTS

6.1 This chapter gives guidance on the appropriate level of assessment to be used when assessing the potential impacts from routine runoff, spillages and flooding arising out of road construction, operation and maintenance projects. For guidance on the level of assessment required, refer to NRA Project Management Guidelines, NRA Environmental Impact Assessment of National Roads – A Practical Guide and NRA Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes.

6.2 The levels of assessment, where applicable, are consequential and progression is dependent on the type of proposed project, the location of the site and local circumstances, as well as the nature of the potential impact (routine runoff, spillages, flooding). For example, where sensitive receptors (e.g. a Special Area of Conservation (SAC), Ramsar Site or a Flood Zone) are identified during the scoping process, direct progression to detailed assessment may be appropriate. The process is also cyclical and is only completed when either no adverse impacts are predicted or other options avoid, treat or mitigate the potential impact, or an adverse impact is deemed to be outweighed by a beneficial impact. Where there is an adverse impact resulting in a change of project, design or mitigation or treatment, there is an obligation to re- assess the changed design or efficacy of treatment. The relationship between assessment level and project stage is shown in Figure 6.1.

6.3 An important part of the process is liaison with the EPA, IFI, OPW, NPWS, Local Authorities and the NRA where appropriate. This not only serves to acquire information, but to consult on levels of assessment necessary and the outcomes, this will ultimately save time and costs, and result in better solutions.

Methods of Assessment

6.4 Each possible impact has standard methodologies, which will normally be deployed. For example, for flooding, this may include the analysis of bridge afflux and floodplain storage. For water quality this may involve compliance of water quality standards for drinking water, fisheries and the general water environment for specific pollutants. For spillage it will involve an assessment of the risks of an incident within the length of road under consideration. The methodologies for each topic are set out in Appendix A, with worked examples in Appendix C. Figure 6.2 shows the approach to be used.

6.5 Figure 6.3 gives an indication of the stage of the project at which detailed calculations of crossing afflux and associated flooding problems need to be taken into account.

<table>
<tr><td colspan="2"></td><td colspan="3">Stage of project</td></tr>
<tr><td colspan="2"></td><td>Establishing Feasibility Considering Options</td><td>Evaluating Options</td><td>Evaluation of Preferred Option</td></tr>
<tr><td rowspan="3">Level of Assessment</td><td>Scoping</td><td>Essential</td><td>Essential if project enters at this stage</td><td>Essential if project enters at this stage</td></tr>
<tr><td>Simple Assessment</td><td rowspan="2">Greater level of detail for higher potential impact</td><td colspan="2" rowspan="2">Assessments reviewed as more data becomes available</td></tr>
<tr><td>Detailed Assessment</td></tr>
</table>

Figure 6.1: Levels of Assessment Needed at Various Stages of Project Development

Scoping

6.6 The levels of assessment required at each phase of a National Road Scheme are set out in the NRA Project Management Guidelines, Guidelines for the Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes and NRA Environmental Impact Assessment for National Roads – A Practical Guide.

6.7 A desk-based exercise is required at the early phases of a National Road Scheme to determine if there is need for any assessment of the impact of the project on the water environment. It is also a liaison and data collection exercise giving opportunity for the EPA, IFI, OPW and NPWS and other bodies to register concerns or particular requirements during the assessment process. It will need a full appreciation of the proposed works and some knowledge of the landscape, hydrogeology and drainage pattern and process in which the project is taking place. Depending on the project, this may be over a catchment/river basin, coastal area or local specific length of watercourse.

6.8 An assessment will be required where there is a potential for any road project to adversely affect water quality, flood risk or spillage risk. For example, if the answer to any of the following is yes, some form of assessment will be required:

a) Will the project affect an existing watercourse or floodplain?

b) Will the project change either the road drainage or natural land drainage catchments?

c) Will the project lead to an increase in traffic flow of more than 20%?

d) Will the project change the number or type of junctions?

e) Is any of the project located within a floodplain?

f) Will earthworks result in sediment being carried to watercourses?

g) Will the project allow drainage discharges to the ground?

Where these scenarios definitely are not the case, no assessment will normally be required. If there is any doubt, assessment should be carried out.

Simple Assessment

6.9 This level of assessment, whilst termed ‘simple’, can vary in its complexity depending upon the level or knowledge and sophistication of the assessment tools available within a subject area. The key feature of the simple assessment is the level of information required to arrive at an understanding of potential risks. On the whole a simple assessment is largely a desk-based exercise using the collected data to determine if there is a potential for impact (from routine runoff, spillage and/ or flooding) on the water environment. For example, to identify the potential impact of routine runoff on surface waters, Method A would be used (as represented in HAWRAT). For groundwater, Method C the groundwater protection response would consider the vulnerability of the aquifer. For spillage, Method D would be used to consider local collision data, existing incident response arrangements and the vulnerability of receiving water bodies. For flooding, Methods E and F would identify areas at risk of flooding and the consequences of the proposed project. Where the simple assessment identifies that there are likely to be no impacts on the water environment due to the project, no further assessment will usually be required. Where potential impacts are required, an assessment will normally be required at the detailed level.

Detailed Assessment

6.10 This will generally build upon the desk-based exercise by supplementing it with information collected on site that enables a more detailed site-specific quantitative assessment to be made for each of the Methods described in Appendix A. At this level, if it is identified that further detailed assessment is required for flooding or spillage risk, this will require close consultation with the EPA, IFI, OPW and NPWS. It may also involve specialist/particular surveys and monitoring, which need to be determined at an early stage as they may have implications for programmes and budgets. In all instances the methodology to be adopted should be agreed with the NRA or local authority.

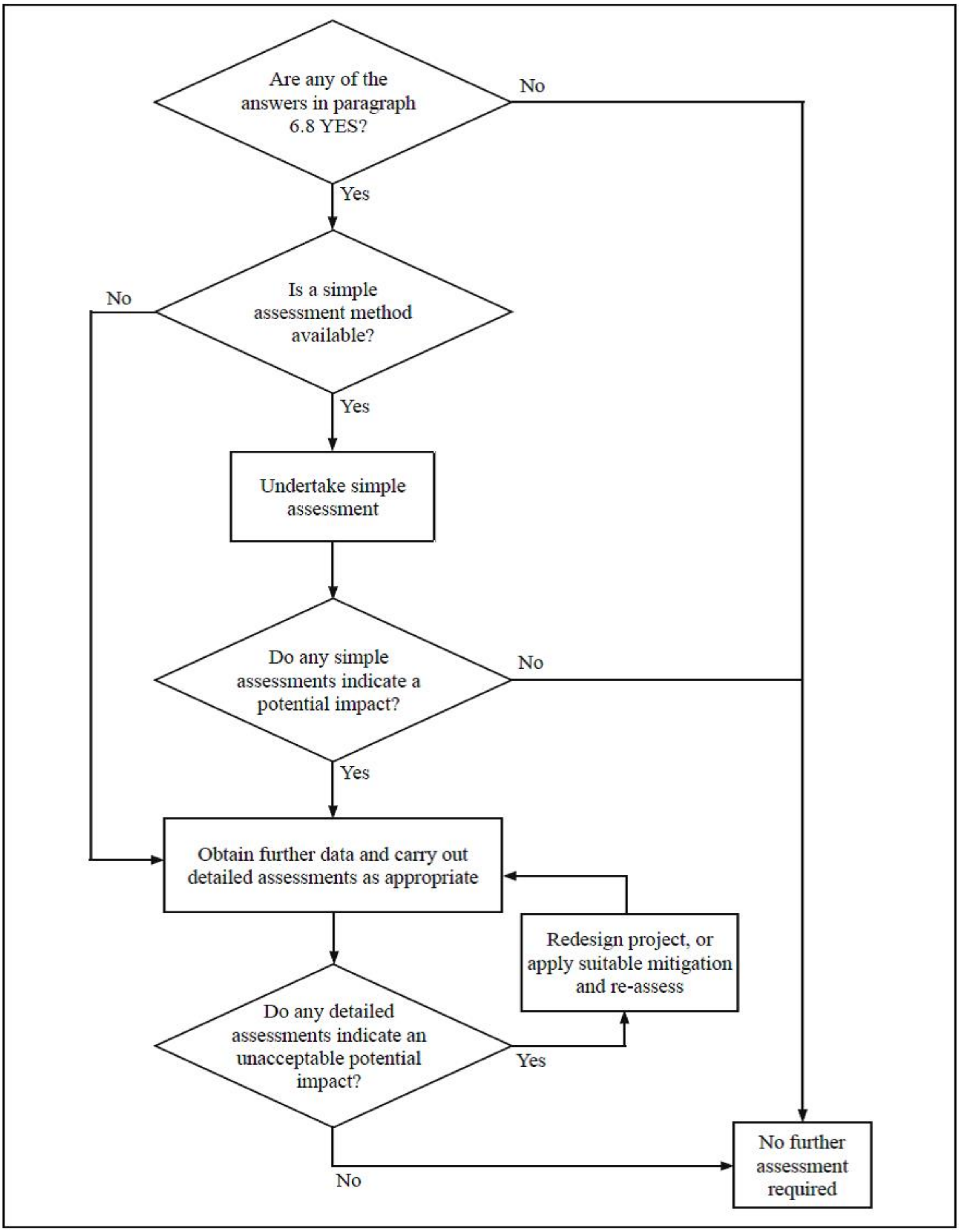

Figure 6.2: Procedure for Assessment of Potential Impacts to the Water Environment

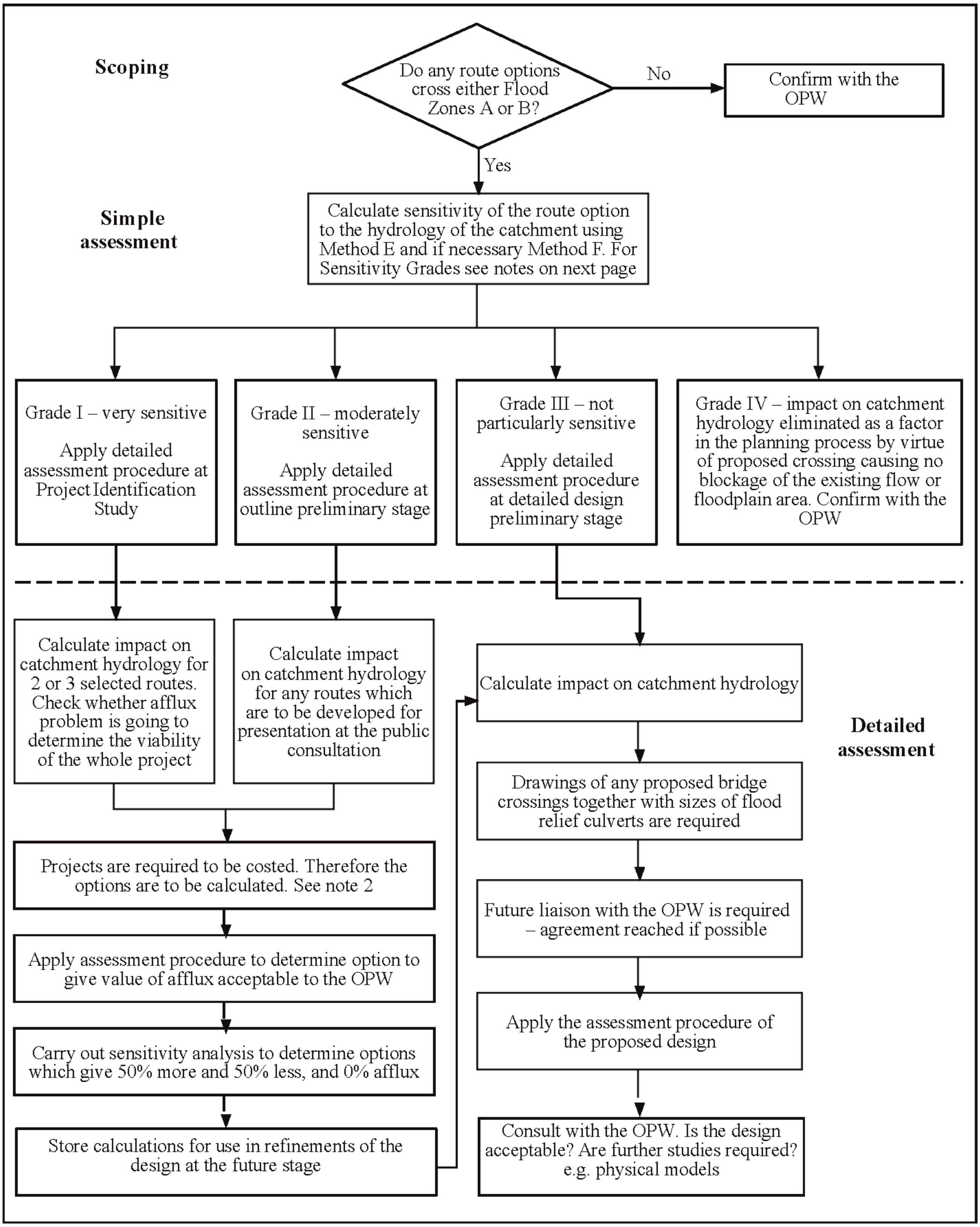

Figure 6.3: Flowchart for Implementing the Assessment of Flood Risk due to Projects Crossing a Floodplain

Notes to Figure 6.3

1. Estimate the difference in cost between providing the maximum feasible flow width (total width of floodplain) and the minimum feasible flow width (width of existing channel). Refer to www.opw.ie/en/floodriskmanagement/ for information regarding flood risk and construction or alteration of watercourse infrastructure. Refer to www.floodmaps.ie and www.cfram.ie/pfra for information regarding flood risk. Using the estimated value of cost difference, calculate what proportion of the overall cost of the route option this represents.

2. The greater this proportion, the more sensitive the route option to the catchment hydrology problem and the earlier it is necessary to carry out an assessment of the impact.

% of the overall route cost		**Effect on project of catchment hydrology**
>25%	Grade I	Very sensitive
5-25%	Grade II	Moderately sensitive
2 – 5%	Grade III	Not particularly sensitive
<2%	Grade IV	Of minimal sensitivity, hence provide maximum flow area and ensure no increase in blockage of the existing flow area

3. The location of the route crossing should also be taken into account. For example, a route crossing in a more rural area, e.g. where only agricultural fields may be flooded could be classed as a Grade I. However, as it only impacts agricultural land, it would not be as sensitive as a similar route option in an urban area. This should also be identified as it will influence the cost and regulatory approval for the route option.

4. To simplify the calculation at this stage when a large number of outline crossing designs are being examined, any floodplain culverts should be included representing them as an equivalent flow area under the main bridge opening i.e. the width of main opening is increased in the calculation procedure to allow for the effects of flood relief culverts. Calculation of the effects of loss of floodplain storage should be omitted at this stage.

7. REPORTING

General

7.1 When reporting the potential effects of a road project on the water environment, a completed Table B.1 (Summary of Potential Effects) should be supported by the results of the assessment methods as well as other technical and qualitative information sufficient to provide a transparent decision-making process. The results of the assessments may be intended for inclusion in the Environment Impact Statement (EIS) to document and support decision making. The results should be capable of bearing public scrutiny and debate and should, therefore, be robust enough to withstand such scrutiny. Records of assessments, consultations, analyses and conclusions should be comprehensive, meticulous and consistent. For further general guidance on reporting potential effects, the following documents should be consulted:

a) NRA Project Management Guidelines;

b) EPA Guidelines on the Information to be Contained in Environmental Impact Statements;

c) EPA Advice Notes on Current Practice (in the preparation of Environmental Impact Statements;

d) NRA Environmental Impact Assessment of National Road Schemes – A Practical Guide;

e) NRA on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes.

7.2 The assessments will produce reports in various formats for different purposes. Technical reports on data collection or fieldwork may often be stand-alone documents, but they should be prepared bearing in mind that certain aspects may contribute to the environmental plans or management plans (or equivalent) for the scheme.

7.3 Reports should conform to the NRA preferred style of formatting, and observe any protocols for the presentation of electronic documents.

7.4 Reports should be prepared on the results of all assessments, whether at Scoping, Simple or Detailed level, giving careful consideration to how much detail is required for the particular stage in scheme delivery and decision making process. The results of assessments should contribute to the NRAs environmental databases.

Scoping Assessment Reporting

7.5 Full Details of scoping requirements for EIA are set out in the NRA Environmental Impact Assessment of National Road Schemes - A Practical Guide. The following sections provide guidance on the reporting of any scoping exercise. The following sections are provided for guideline purposes.

7.6 The report should record the following:

a) the results of any scoping criteria found in paragraph 6.8;

b) if applicable, the reason(s) why any further assessment is not warranted;

c) where further assessment is necessary, which methods (of Appendix A Methods A to F) are to be used for subsequent assessment;

d) baseline information;

e) the proposed consultation strategy to be followed.

Simple Assessment Reporting

7.7 The report on the Simple Assessment should contain the following key sections:

a) Introduction/Overview: information on the scheme background and context.

b) Identification of the water features/attributes that may be affected.

c) Method Statement: a description of the assessment sources, and methods adopted for data gathering, fieldwork, evaluation, assessment of impacts and mitigation.

d) Regulatory and Research Framework: the relevant legislation, policy and codes of practice, and the results of relevant consultations, together with a statement of the Project Objectives.

e) Results of assessments from each of the four principal areas considered:

i) Effects of Routine Runoff on Surface Waters (see paragraph 7.8);

ii) Effects of Routine Runoff on Groundwater (see paragraph 7.9);

iii) Spillages (see paragraph 7.10);

iv) Flood Impacts (see paragraph 7.11).

f) Assessment of the importance of the water features/attributes and the magnitude of the impact of the scheme. This should take into account any agreed mitigation measures or strategies, including the likely effectiveness of the mitigation. The impact of the unmitigated scheme should also be reported. There should be a description and discussion of potential alternatives.

g) Significance of effects: the assessment of the significance of the effects on the water environment based on the importance of the attribute and the magnitude of the impact taking agreed mitigation into account.

h) A summary of the potential effects on the water environment (including a completed Table B.1) and a statement identifying any remaining risks or uncertainties.

7.8 For the effects of routine runoff on surface waters, the results of Method A assessments should be reported. These will be the interpreted outputs from Highways Agency Water Risk Assessment Tool (HAWRAT). The full results of each assessment should be reproduced; this includes the ‘Detailed Results’ sheet and the ‘User Parameters’ sheet, both of which are generated when the assessment is saved through the HAWRAT menu (see the HAWRAT Help Guide). Where more than one outfall has been assessed for the scheme under consideration it will be necessary to include a summary table showing the results of each of the assessments undertaken. As a minimum the table should include the outfall number, the Pass/Fail result for solubles and for sediments, the predicted low flow velocity of the receiving water, the deposition index, the annual average concentrations of soluble copper and zinc (and whether these pass or fail the EQSs) and whether mitigating measures should be considered to protect groundwater.

7.9 For the effects of routine runoff on groundwater, the results of Method C groundwater protection response should be reported. As described in Appendix A, Method C, the assessment is carried out using the matrix in Table A.5. The full derivation of each category should be presented, particularly where vulnerability is being updated based on site specific information, the format for which is illustrated in the worked examples (Appendix C, Method C). Where more than one discharge location has been assessed for the scheme under consideration it will be necessary to include a summary table showing the results of each of the assessments undertaken. As a minimum the table should include the soakaway or chainage number, the site specific vulnerability and the response matrix category and the associated design.

7.10 For the assessment of pollution impacts from spillages, the results of Method D risk assessments should be reported, particularly the annual probability of a serious pollution incident and whether this is an acceptable risk. The report should also consider whether mitigating measures are required to protect the water environment and whether a more detailed risk assessment need be undertaken. The full results of each assessment should be reproduced; if the spillage risk assessment has been completed in HAWRAT a summary results sheet labelled 'Spillage Risk' is generated when the assessment is saved through the HAWRAT menu (see the HAWRAT Help Guide). Where more than one outfall has been assessed it will be necessary to include a summary table presenting the results of each of the assessments undertaken.

7.11 For the assessment of flood risk the results of Method E and Method F should be reported. For Method E the report should include, for any water courses within the scheme, the flow rate expected for a flood of 1% annual probability (plus an allowance for climate change) and whether this changes as a result of the scheme. If there is an increase in the expected flow rate the report should consider what mitigation is needed, whether attenuation of the road runoff is required and if so what the required storage volume will be. For Method F the report should include a statement of the expected change in water surface elevations that will result from the scheme (the afflux), the approximate change in floodplain volume and the change in flood potential resulting from a change in runoff. If there is an adverse change then the report should identify mitigation options.

Detailed Assessment Reporting

7.12 Where detailed reporting is required it is probable that consultations will have been held and field surveys undertaken. The detailed report will include details of the methodologies adopted together with the findings from any field surveys and analysis undertaken.

7.13 The report on the Detailed Assessment should contain all the information required on the Simple Assessment plus the following:

a) For the effects of routine runoff on surface waters, if Method B assessments are required, these should be reported in the detailed assessment report. The reported figures should include: the annual average concentrations predicted by HAWRAT, the EQSs (for the appropriate hardness band) and the water quality results from field sampling. Details should also be given of any proposed mitigation and its effect on the result of the assessment.

b) For the effects of routine runoff on groundwater, the assessment should be refined and updated based on additional survey information. The appropriate response should be identified, based on the matrix.

8. MITIGATION OF IMPACTS

Pollution Mitigation Measures

8.1 Where the assessment of the risks of pollution from road runoff shows the need for mitigation, there are several options available. The use of drainage systems to reduce pollution is described in NRA HD 33. Vegetated systems are described in NRA HD 103 Vegetated Drainage Systems for Road Runoff and guidance on design of soakaways is given in NRA HD 118 Design of Soakways. Advice on Grassed Surface Water Channels is given in NRA HD 119 Grassed Surface Water Channels for Road Runoff. When properly selected, designed and built many of these can reduce the pollution risks. Vegetated systems can also enhance aspects of the water environment and landscape as well as benefiting biodiversity, and in such cases should be designed with the assistance of the appropriate specialist for landscape/biodiversity. However, it should be recognised that a primary function of the drainage system can be the attenuation and treatment of road runoff. When considering mitigation of potential impacts to surface waters using the HAWRAT, attention is drawn to paragraphs A.18 to A.20 regarding the interpretation of required treatment, dilution (flow attenuation) and sediment removal.

8.2 Drainage systems may be either active or passive in operation:

a) **Active systems (requiring operators)**
Penstocks, valves, notched weirs.

b) **Passive systems**
Swales, ponds, wetlands, ditches, basins, silt traps, filter drains, soakaways and oil separators.

Many of these passive systems can be termed Sustainable Drainage Systems (SuDS). SuDS are recommended for new developments which have surface water drainage systems draining to the water environment.

8.3 Possible mitigation measures could include the following:

a) source – consider whether it is possible to amend:
  i) road geometry to reduce the spillage risk, or by changing catchment boundaries or cross falls;
  ii) number/location of outfalls;
  iii) choice of routes/route options;

b) pathway – amend:
  i) choice of drainage system, as noted in paragraph 8.1;

c) planning – use of signage, emergency plans, pollution equipment;

d) during construction ensure action is taken on:
  i) bunding;
  ii) routes of temporary traffic diversions;
  iii) storage of hazardous/waste materials;
  iv) procedures for concreting;
  v) wash down areas;

vi) the disposal of surface water runoff from excavations which may be contaminated with silt.

Further guidance on measures to reduce the risks of pollution impact from construction activities is available in the NRA Environmental Assessment and Construction Guidelines and two Construction Industry Research and Information Association (CIRIA) Reports C532 and C648.

8.4 Table 8.1 gives optimum indicative factors by which certain measures can be expected to reduce the risk of a spillage causing a pollution incident, as calculated using Method D (Spillage Risk Assessment), Appendix A. If the risk without the system is found to be P, then the risk with the system in the drainage network is given by P x R_F, where R_F is the risk reduction factor for that system.

Table 8.1: Spillages – Indicative Pollution Risk Reduction Factors

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

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

Flood Mitigation Measures

8.5 If it is impractical to design a project achieving acceptable flood levels, additional works may be required to mitigate the flood level changes caused by the project. Measures may include amending the road geometry, provision of flood relief culverts or, as a last recourse, alterations to the channel, floodplain and other river structures. However, these alterations should not adversely affect the water levels of areas elsewhere in the catchment, but should aim to maintain them at existing levels whilst affording protection to those areas affected by the project.

8.6 The hydrological and hydraulic assessment (Methods E and F, Appendix A) should demonstrate what sustainable options there are for flood level management in the locality. Options such as large-scale straightening or deepening of rivers will not be acceptable to the EPA, IFI, OPW and NPWS unless these options can offer demonstrable improvements to flood risk management and the natural environment. Works of this kind should only be considered when all other options are exhausted, following consultation with the EPA, IFI, OPW and NPWS.

8.7 The purpose of floodplain mitigation measures is to manage floodwater levels in a way that reduces the impact of flooding on the road itself and elsewhere in the catchment. This may include changing the resistance of the floodplain to flood flow, thereby lowering floodwater levels. Floodplain improvements may include:

a) removal of existing obstructions, which may include vegetation (however, the downstream effects need to be considered, so as not to increase flooding elsewhere);

b) ground lowering;

c) new openings in existing embankments (to increase conveyance);

d) new flood storage areas;

e) local embankments to protect isolated features (particularly in association with (ii) above).

Any improvements made should not have a detrimental effect on the performance of the project under any other flow conditions or result in a major downstream increase in flood levels.

8.8 Flood mitigation measures require consideration and investigation before implementation. For example, channel alteration works will have implications for river maintenance, as the river will try to recover its original shape unless regular maintenance is undertaken. Berms and floodplain lowering may produce waterlogging, with consequent land use and maintenance problems. Berms may also prevent access to the river for maintenance or public enjoyment. The cost of such increased maintenance should be taken into account in the project assessment.

8.9 It should be noted that any increase of conveyance can increase the velocity of floodwaters possibly causing scouring or a flooding problem elsewhere. This should be taken into account within the hydraulic assessment.

8.10 In order to assess the impact of flood mitigation measures an unsteady state hydraulic model will be required to simulate the changes in water levels both upstream and downstream.

Flood Protection Measures

8.11 Where new road crossings increase the risk of flooding it will be necessary to include local flood protection measures as part of the road project to reduce the risk to an acceptable level. These may include flood walls, flood protection embankments or levees, flood storage areas and other measures.

8.12 Flood walls or embankments could be constructed around areas where flood risk has increased, making due allowance for the discharge of local drainage water during a flood. In this case the impact of loss of floodplain storage caused by embanking part of the floodplain should be considered with regard to effects on upstream and downstream flood levels.

8.13 In constructing any flood protection measures it is common to apply a fluvial freeboard above the design flood level. Refer to www.opw.ie/en/floodriskmanagement/ for OPW design requirements. A risk based calculation for specific locations should be carried out.

8.14 Care should be taken to ensure that the construction of these measures will not have a detrimental impact on upstream or downstream habitats of biodiversity importance, though in some instances they may be beneficiaries.

8.15 Advice on the design of culverts and outfalls is given in NRA HD 107 and advice on mitigating the possible impact of land drainage on roads is given in NRA HD 106. Refer to www.floodmaps.ie and www.cfram.ie for information regarding flood risk.

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c) Road Construction Details (NRA RCD) (MCDRW 4)

9.2 NRA Design Manual for Roads and Bridges (NRA DMRB)

a) NRA HD 33 Drainage Systems for National Roads

b) NRA HA 33 Design of Earthworks Drainage, Network Drainage, Attenuation and Pollution Control

c) NRA HD 103 Vegetated Drainage Systems for Road Runoff

d) NRA HD 119 Grassed Surface Water Channels for Road Runoff

e) NRA HD 118 Design of Soakaways

f) NRA HD 106 Drainage of Runoff from Natural Catchments

g) NRA HD 107 Design of Outfall and Culvert Details

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10. ACRONYMS

AADT	Annual Average Daily Traffic
BFI	Base Flow Index
CAR	Controlled Activities Regulations
CEMP	Construction Environmental Management Plan
CIRIA	Construction Industry Research and Information Association
DMRB	Design Manual for Roads and Bridges
DOC	Dissolved Organic Carbon
EA	Environment Agency (England and Wales)
EIA	Environmental Impact Assessment
EMC	Event Mean Concentration
EMSC	Event Mean Sediment Concentration
EPA	Environment Protection Agency
EQS	Environmental Quality Standard
EU	European Union
FEH	Flood Estimation Handbook
FRA	Flood Risk Assessment
FSR	Flood Studies Report
GPR	Groundwater Protection Response
GSI	Geological Survey of Ireland
HA	Highways Agency
HADDMS	Highways Agency Drainage Data Management System
HAWRAT	Highways Agency Water Risk Assessment Tool
HGV	Heavy Goods Vehicle
IOH	Institute of Hydrology
NRA	National Roads Authority
PAH	Polycyclic Aromatic Hydrocarbons

PEL	Probable Effects Level
PNEC	Probable Non-Effect Concentration
Q_{95}	95% low flow (in rivers)
RBD	River Basin Distrct
RBMP	River Basin Management Plan
RL	Road Length
RST	Runoff Specific Threshold
SAC	Special Area of Conservation
SFRA	Strategic Flood Risk Assessment
SPAs	Special Protection Areas (ecology)
SPA	Source Protection Areas
S-P-R	Source-Pathway-Receptor
SR	Service Reservoirs
SuDS	Sustainable Drainage Systems
TAN	Technical Advice Note
TEL	Threshold Effects Level
WFD	Water Framework Directive
WQS	Water Quality Standard

11. GLOSSARY

Afflux	The increase in water level caused by a restriction to flow.
Aquatic	Growing, living or found in water.
Aquifer	A subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.
Base Flow Index	The proportion of the flow in a watercourse made up of groundwater and discharges. Base flow sustains the watercourse in dry weather.
Compound	A substance that contains atoms of two or more chemical elements held together by chemical bonds.
Deposition Index	A dimensionless index value that considers the extent of sediment coverage on the stream bed.
Ecological status	An expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters, classified in accordance with Annex V of the Water Framework Directive (WFD). Biological as well as supporting hydromorphological and physico-chemical quality elements are to be used in the assessment of ecological status.
Environmental Quality Standard	Specifies the absolute compliance concentration or range for a water quality element in the environment failure of which will be reported to the European Commission.
Event Mean Concentration	The concentration measured in a flow weighted composite sample made up from discrete samples collected at a fixed sampling time interval during a runoff event.
Flood Zone	A geographic area for which the probability of flooding from rivers, estuaries or the sea is within a particular range as defined within The Planning System and Flood Risk Management Guidelines.
Groundwater	All water which is below the surface of the ground in the saturation zone (below the water table) and in direct contact with the ground or subsoil.
Groundwater body	A distinct volume of groundwater within an aquifer or aquifers.
Groundwater status	The general expression of the status of a body of groundwater, determined by the poorer of its quantitative status and its chemical status.

Heavy metals	Lead (Pb), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Manganese (Mn), Iron (Fe), Nickel (Ni), and Cobalt (Co) – a group of ferrous and non-ferrous metals commonly known as heavy metals found in motorway or road surface runoff. Pb is a specific product of vehicle exhaust emissions from petrol driven engines, Zn is present in car tyres and motor vehicle components and Cu, Cr and Cd are released principally as corrosion products.
Lake	A body of standing inland surface water.
Leaching	The washing out of a soluble constituent.
Manning's n	The effective channel roughness which is a function of channel velocity, flow area and channel slope. Vegetation can have a major influence on Manning's n and may account for marked seasonal variation in n. Channel irregularity may also increase n, as will sharp curvature in a channel.
Oil	Viscose liquid of vegetable or mineral origin. Inflammable and usually insoluble in water. Chiefly composed of Carbon and Hydrogen.
Organic	The description of a material composed of Carbon combined with Hydrogen and also often containing Oxygen, Nitrogen and other elements.
Probable Effects Level	The probable effects level (PEL) is the concentration above which toxic effects are observed in aquatic fauna on most occasions.
Q_{95}	The flow rate of the watercourse that is exceeded for 95% of the time.
Q_{BAR}	Median annual peak flow in a watercourse.
Q_{MED}	Mean annual flood event in a watercourse.
Quantitative status	An expression of the degree to which a groundwater body is affected by direct and indirect abstractions.
Ramsar site	Wetland site classified under the Ramsar convention.
Reach	A stretch of a river used in the assessment of river water quality.
River	A body of inland water flowing for the most part on the surface of the land but which may flow underground for part of its course.
River Basin District (RBD)	The area of land and sea, made up of one or more neighbouring river basins, together with their associated groundwaters and coastal waters, as the main unit for management of river basins.
River Basin Management Plan	Under the WFD, all river catchments are assigned to administrative River Basin Districts (RBDs). The River Basin Management Plans (RBMPs) set out environmental objectives for all groundwater and surface water bodies and Protected Areas within an RBD. The plans include a programme of measures to meet these objectives.

Runoff specific threshold	Time dependent (24 hour or six hour) soluble pollutant concentration above which adverse effects may be observed in aquatic fauna.
Salmonid	Salmon and trout. These fish are generally found in waters that are fast flowing stretches of river that have a high oxygen content and a low level of nutrients.
Surface water	All inland waters, except groundwater, and includes transitional waters and coastal waters; territorial waters are included as surface waters for the purposes of the Directive insofar as chemical status is concerned.
The precautionary principle	Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
Threshold Effects Level	The TEL is the concentration below which toxic effects in aquatic fauna are extremely rare.
Transitional water	Bodies of surface water in the vicinity of river mouths which are partly saline in character as result of their proximity to coastal waters but which are substantially influenced by freshwater flows.
Unproductive strata	These are geological strata with low permeability that have negligible significance for water supply or river base flow.

12. ENQUIRIES

12.1 All technical enquiries or comments on this document, or any of the documents listed as forming part of the NRA DMRB, should be sent by e-mail to infoDMRB@nra.ie, addressed to the following:

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National Roads Authority

Design Manual for Roads and Bridges
(NRA DMRB)

Amendment No. 1 (June 2015) to NRA Design Manual for Roads and Bridges Volume 4, Section 2, Part 1
NRA HD 45 - Road Drainage and the Water Environment
Dated March 2015

The NRA Design Manual for Roads and Bridges (NRA DMRB) NRA HD 45, dated March 2015 is amended as follows:-

1. Page 3, Clause 1.9

   Clause 1.9 Implementation is amended.

APPENDIX A: ASSESSMENT METHODS

Assessment of Pollution Impacts from Routine Runoff to Surface Waters

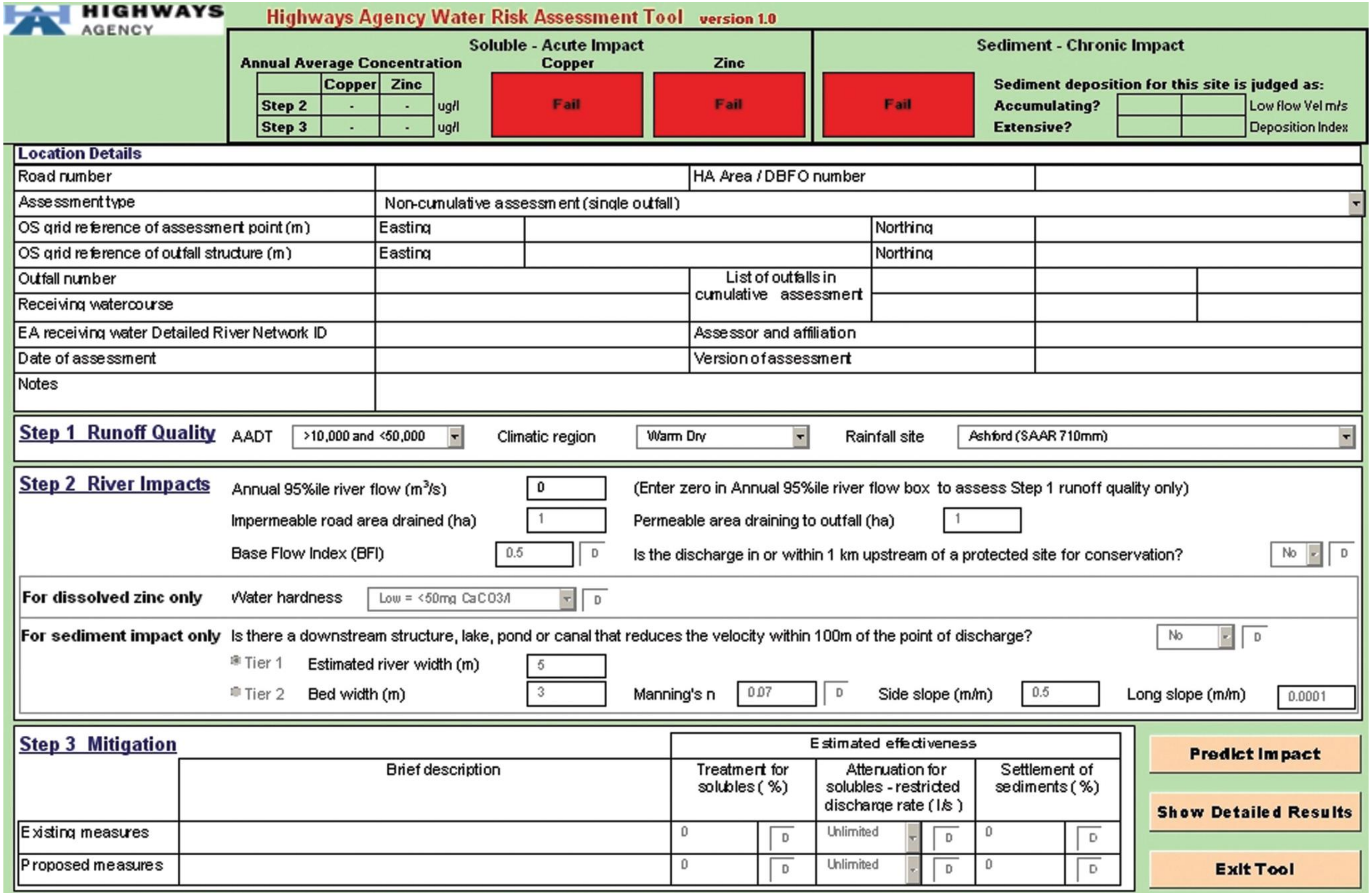
Method A – Sample Assessment

A.1. The assessment method for determining whether routine runoff is likely to have an ecological impact on receiving surface watercourses uses the Highways Agency Water Risk Assessment Tool (HAWRAT). HAWRAT is designed to make an assessment of the short-term risks related to the intermittent nature of road runoff. An assessment of the long-term risks over the period of one year is also required (paragraph A.11) to complete the risk assessment process. The method of assessment used by HAWRAT is acknowledged by the Environment Protection Agency (EPA) and therefore the outputs should be used in Environmental Impact Assessments (EIAs).

A.2. The assessment should begin with an understanding of the natural drainage network operating in the vicinity of the outfalls of interest, notably the presence and position of downstream confluences and river structures such as lakes and weirs. Such data can be obtained from local mapping, www.opw.ie/en/floodriskmanagement/, http://www.floodmaps.ie/ and http://www.epa.ie/water/ and other appropriate references. This knowledge is particularly important for establishing whether the discharge from two or more outfalls should be combined for assessment purposes (paragraph A.15).

A.3. HAWRAT is a Microsoft Excel application which can be downloaded from (HADDMS) www.haddms.com. The principal features and workings of HAWRAT are discussed in Chapters 3 and 5. Given below is an overview of how to use the tool and the input parameters required. The Help Guide and Technical Manual, which can be downloaded with HAWRAT, gives a full description of the tool and how to use it.

A.4. The user interface of the tool is shown in Figure A.1. The user is required to enter a series of parameters on this interface which relate to the outfall under assessment. These may be actual values or values within a range that can be selected from a drop down menu. Once the parameters have been entered the ‘Predict Impact’ button is clicked. The tool then calculates the runoff pollutant concentrations associated with a ten year series of rainfall events and the coincident flow in the receiving watercourse during each event. These calculations may take up to a minute, after which the tool displays either Pass or Fail for each of the pollutants considered. The ‘Detailed Results’ sheet gives a more detailed explanation of the outputs of the last run. The Help Guide and Technical Manual provides further explanation of the internal processes of the tool and the calculations performed. The logic flowcharts which HAWRAT follows are shown in Figures A.2 (soluble pollutants) and A.3 (sediment-bound pollutants).


HIGHWAYS AGENCY

Highways Agency Water Risk Assessment Tool version 1.0

Soluble - Acute Impact

Annual Average Concentration

	Copper	Zinc	
Step 2	-	-	ug/l
Step 3	-	-	ug/l

Copper: Fail
Zinc: Fail

Sediment - Chronic Impact

Fail

Sediment deposition for this site is judged as:
Accumulating? Low flow Vel m/s
Extensive? Deposition Index

Location Details

Road number		HA Area / DBFO number	
Assessment type	Non-cumulative assessment (single outfall)		
OS grid reference of assessment point (m)	Easting	Northing	
OS grid reference of outfall structure (m)	Easting	Northing	
Outfall number		List of outfalls in cumulative assessment	
Receiving watercourse			
EA receiving water Detailed River Network ID		Assessor and affiliation	
Date of assessment		Version of assessment	
Notes			

Step 1 Runoff Quality AADT >10,000 and <50,000 Climatic region Warm Dry Rainfall site Ashford (SAAR 710mm)

Step 2 River Impacts

Annual 95%ile river flow (m^3/s) 0 (Enter zero in Annual 95%ile river flow box to assess Step 1 runoff quality only)

Impermeable road area drained (ha) 1 Permeable area draining to outfall (ha) 1

Base Flow Index (BFI) 0.5 D Is the discharge in or within 1 km upstream of a protected site for conservation? No D

For dissolved zinc only Water hardness Low = <50mg CaCO3/l D

For sediment impact only Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge? No D

Tier 1 Estimated river width (m) 5

Tier 2 Bed width (m) 3 Manning's n 0.07 D Side slope (m/m) 0.5 Long slope (m/m) 0.0001

Step 3 Mitigation

	Brief description	Estimated effectiveness: Treatment for solubles (%)		Attenuation for solubles - restricted discharge rate (l/s)		Settlement of sediments (%)	
Existing measures		0	D	Unlimited	D	0	D
Proposed measures		0	D	Unlimited	D	0	D

Predict Impact

Show Detailed Results

Exit Tool

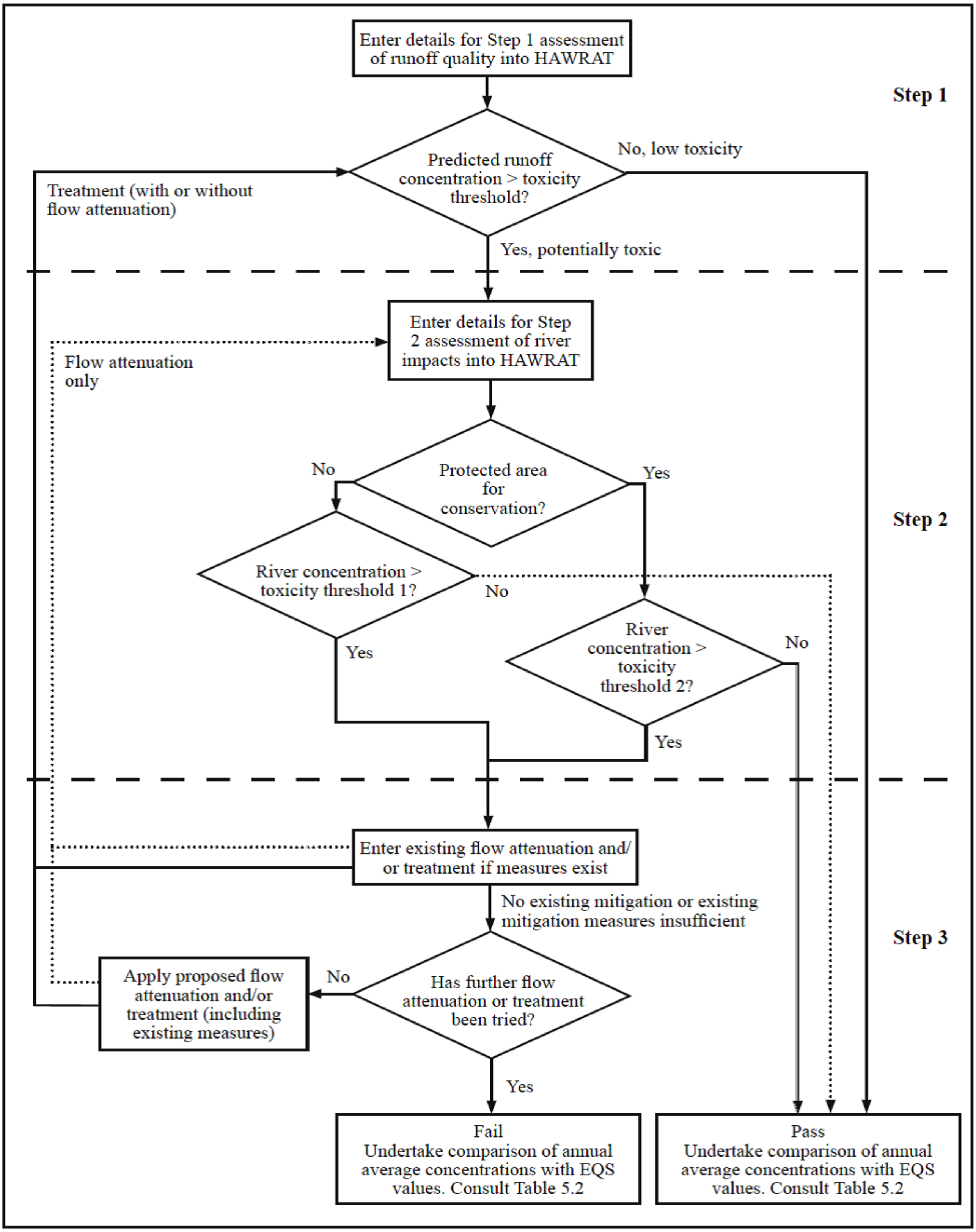


Figure A.2: Procedure for Assessment of Soluble Pollutants

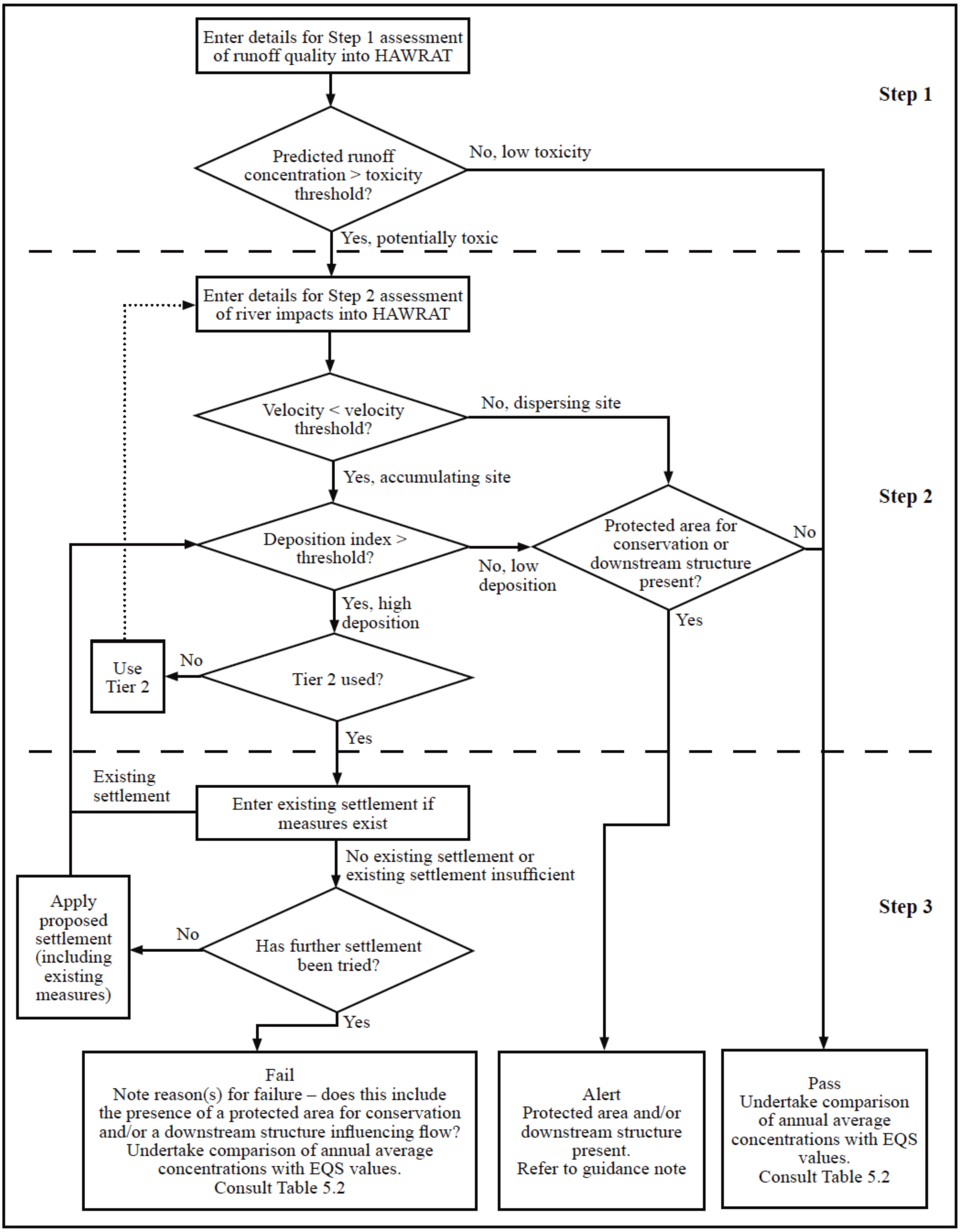


Figure A.3: Procedure for Assessment of Sediment-Bound Pollutants

A.5. HAWRAT includes three assessment stages.

a) Step 1 allows an initial check to assess the quality of the direct road runoff against the toxicity thresholds assuming no in-river dilution and no treatment or attenuation. If Step 1 shows that the toxicity is acceptable, then no further assessment is necessary. To perform a Step 1 assessment the following information is required:

i) The existing or design traffic flow of the road (two-way Annual Average Daily Traffic (AADT)). One of three traffic bands can be selected from:

≥10,000 to <50,000

≥50,000 to <100,000

≥100,000

ii) The climatic region and rainfall data used in HAWRAT is based on UK data. Rainfall data for Ireland can be obtained from Met Éireann. The standard annual average rainfall (SAAR) value for the site under consideration can then be compared to the UK values embedded in HAWRAT and the closest value chosen.

For this initial check of runoff quality, the ‘Annual 95%ile river flow’ (Q_{95} low flow) needs to be set to zero.

b) For the acute impacts of soluble pollutants, Step 2 takes account of the diluting capacity of the watercourse which receives the road runoff. For the chronic impacts of sediment-bound pollutants, Step 2 takes account of the likelihood and extent of sediment deposition. Step 2 contains two tiers of assessment for sediment-bound pollutants: Tier 1 is a quick, conservative and desk-based assessment; Tier 2 is a more detailed assessment requiring a site visit to measure the dimensions of the watercourse. Appendix D contains a field log sheet designed to assist in site visits and should, if fully completed, ensure all information is captured and repeat visits are minimised. If a Tier 1 assessment indicates there is no risk then unnecessary work for a Tier 2 assessment is avoided. Step 2 assumes no mitigation. To perform a Step 2 assessment the following information is required:

i) the annual 95%ile river flow (m3/s), or Q_{95} flow, discussed in paragraphs A.6;

ii) the Base Flow Index (BFI) (if this is unknown 0.5 can be used as a default, refer to the ‘Low- Flow prediction for ungauged river catchments in the Ireland’ for guidance on calculation of low flows);

iii) the impermeable road area which drains to the outfall (ha);

iv) any permeable (non-road surface) area which also drains to the outfall (ha), discussed in paragraph A.7;

v) whether the discharge is likely to impact on a protected site for conservation, discussed in paragraph A.8;

vi) the hardness of the receiving water (mg CaCO3/l);

vii) whether there is a downstream structure, lake or pond that reduces the river velocity near the point of discharge (discussed in paragraph A.9);

viii) for Tier 1 assessments, an estimate of the river width (m); and

ix) for Tier 2 assessments, site measurements of bed width (m), side slope (m/m), long slope (m/m) and an estimate of Manning’s n.

c) For soluble pollutants, Step 3 allows the effectiveness of existing and proposed treatment systems to be assessed. Assessments can be made iteratively for:

i) the effect of attenuating the flow (l/s) – limiting the discharge rate from the outfall to increase in river dilution; and

ii) reducing the pollutant concentration through treatment (% treatment).

For sediment-bound pollutants, recognising that settlement is the only viable 'treatment' option, if the site is predicted to accumulate sediments, the tool reports the percentage of settlement required to ensure the extent of sediment coverage complies with the threshold deposition index value. Further information on how to interpret the mitigation values required at Step 3 is given in paragraphs A.18 to A.20. Available data on the treatment efficiencies and degree of settlement offered by conventional treatment systems is limited and specialist judgement is likely to be needed if mitigation is required.

Influencing Factors

A.6. The annual 95%ile river flow of the watercourse (Q_{95}) is the flow exceeded in the river for 95% of the time. Where no gauging data are available this parameter can be calculated using the methods discussed in paragraph 5.21. Where the value of Q_{95} is less than 0.001 m^3/s (either calculated or from gauging data), a figure of 0.001 m^3/s should be used in the assessment method. Alternatively, the receiving water course could be considered as a soakaway, and the appropriate groundwater assessment method used (Appendix A, Method C).

A.7. For the purpose of calculating a value to enter into HAWRAT for impermeable and permeable areas, only surface water runoff deriving from the road-cross section should be included. As defined in NRA HD 106 this 'Interior Catchment' includes the road surface, verges and adjacent cuttings or embankments. In HAWRAT, runoff from the permeable area which drains to the outfall is assumed to be free from road derived pollutants and has the effect of increasing the dilution of soluble pollutants derived from the impermeable area. It should be noted that the HAWRAT calculations are not particularly sensitive to the permeable area parameter as the associated runoff coefficient is low. If the size of the permeable area is not clear then the precautionary approach is to assume a value of zero.

A.8. At Step 2, HAWRAT asks whether the outfall(s) being assessed discharge upstream of sites that are protected for nature conservation. Examples of protected sites include: Natura 2000 (Special Area of Conservation (SACs) and Special Protection Areas (SPAs)) sites. Non-designated sites may also be especially sensitive to impacts. Where these sites lie within 1 km downstream of the outfalls the parameter for HAWRAT should be switched to 'yes'. For assessment of soluble pollutants, where protected sites are present, stricter exceedance frequencies for the Runoff Special Thresholds (RSTs) will be applied. For assessment of sediment-bound pollutants, the assessment thresholds remain the same but in situations that would otherwise Pass, the tool reports an Alert result indicating that the presence of protected nature sites will require further site-specific consideration. In such cases, further measures should be agreed with the EPA, IFI and NPWS.

A.9. At Step 2, HAWRAT also asks whether there is any downstream structure, lake or pond that reduces the river velocity within 100 m downstream of the point of discharge. While the site immediately downstream of the outfall may be regarded as a dispersing site, such features as weirs and ponds may slow the river velocity and cause accumulation of potentially contaminated sediments. For sites that would otherwise pass the HAWRAT assessment of sediment-bound pollutants, the presence of these features will lead to an Alert result indicating the need for further site-specific consideration. The presence of downstream features does not affect the solubles assessment.

Summer Exceedances

A.10. In addition to the number of exceedances of the RSTs, the ‘Detailed Results’ sheet of HAWRAT provides information on the number of exceedances occurring during the summer. This provides further insight as to what time of year ecological impacts might occur and thereby informs the need for (and design of) mitigation solutions. For example, the discharge may impact a SAC that is designated as such in order to protect a particular aquatic population. If the RST exceedances coincide with the breeding and development periods of that species then there may be a greater impact than if the exceedances occurred at another time of year. The default ‘summer’ period of HAWRAT is set to the six months from April to September (inclusive) when many aquatic species produce their offspring to take advantage of higher water temperatures and greater food availability.

Assessment of Annual Average Pollutant Concentrations

A.11. The EPA, IFI and NPWS require that annual average concentrations in the receiving watercourse do not exceed published WFD EQSs. EQSs are based on annual average concentrations. In addition to determining the short-term risks using HAWRAT, an assessment of the risks over the duration of a year is, therefore, required to complete the risk assessment process. The logic flowchart which should be followed for the assessment of long-term risks over the period of one year is shown in Figure A.4.

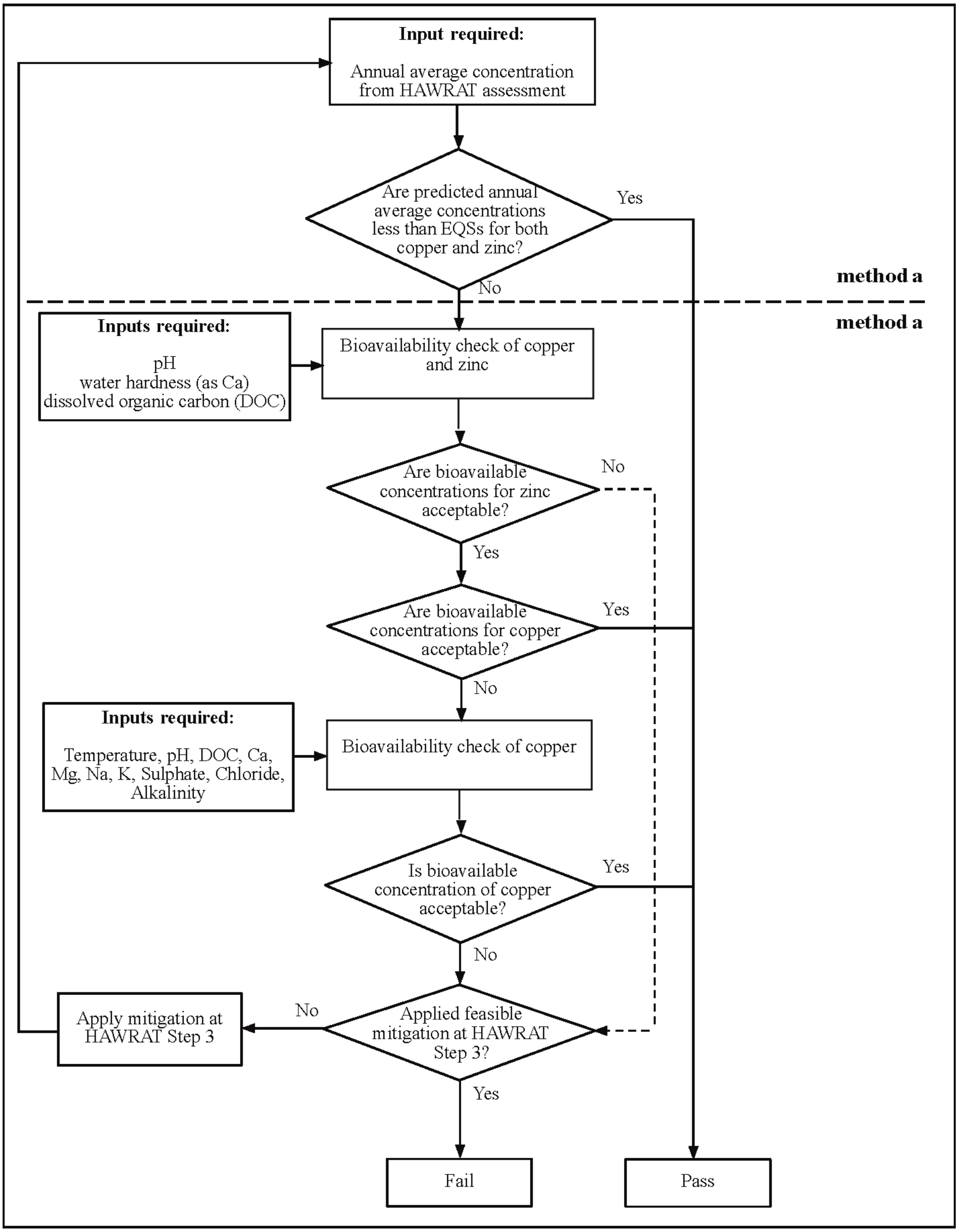


Figure A.4: Procedure for Assessment of Annual Average Impacts from Routine Road Runoff

A.12. HAWRAT reports the annual average concentration of dissolved copper and dissolved zinc at Step 2 (in river before mitigation). In calculating the annual average concentrations of dissolved copper and dissolved zinc, HAWRAT assumes the background/upstream concentrations are zero. This enables an assessment of the added risk rather than total risk, i.e. the additional risk to organisms in the receiving water when they are exposed to road runoff. These values should be compared with the EQSs to determine whether there is a long-term impact or not. HAWRAT also reports the annual average concentration at Step 3 (after mitigation), so if mitigation is included then these values should be used for comparison with the EQSs. It should be noted that incorporating flow attenuation into the drainage system will not reduce the annual average concentration (all the annual runoff will still be discharged within the year), only treatment of the soluble pollutants prior to discharge will reduce the annual average concentrations.

A.13. Following the logic of Figure A.4, if the predicted annual average concentrations are found to be below the EQS thresholds then no further action need be taken with respect to long-term risks (if potential short-term impacts have been identified through HAWRAT then Table 5.2 should be consulted for advice on how to proceed). If the predicted annual averages exceed either of the EQS values for copper or zinc then the bioavailability of these metals will need to be assessed using a Method B (detailed assessment).

Point of Assessment and Aggregation of Outfalls

A.14. The point of assessment should be within an identified natural downstream receiving watercourse (or heavily modified watercourse if appropriate). If a discharge is into a ditch or drain that discharges into a natural watercourse after a short distance then the designer (for the purpose of data input to HAWRAT) should focus the environmental assessment on the natural watercourse and not the ditch or drain. In many cases a judgement will be required at a local level in relation to the point of assessment and where there is any doubt the EPA, IFI or NPWS should be consulted.

A.15. When assessing potential impacts each outfall should be individually assessed in the first instance and the point of assessment clearly identified. Where more than one outfall discharges into the same reach of a watercourse the combined effects will be more significant. In these circumstances the outfalls should be aggregated for purposes of cumulative assessment within HAWRAT (subject to the proximity of the outfalls discussed in paragraph A.16). To aggregate the outfalls the drained areas are simply added together. Care should be taken over the Q_{95} value used as, in small streams, this may increase significantly along the reach being assessed. The point for cumulative assessment should be clearly identified and should be downstream of the last outfall in the reach. For this purpose a reach is defined as a length of watercourse between two confluences. The reason for this is that the available dilution and stream velocity will naturally change at confluences and influence the assessment.

A.16. Reaches can vary greatly in length and, for assessment of impacts associated with soluble pollutants, where the reach is longer than 1 km (measured along the watercourse) only outfalls within 1 km should be aggregated for assessment. When assessing the potential impacts associated with sediment-bound pollutants, where the reach is longer than 100 m only outfalls lying within 100 m should be aggregated for assessment. Beyond 100 m the sediment, if it settles at all, is likely to be sufficiently diluted with natural sediment. If it is not clear whether outfalls should be aggregated, the precautionary approach is to combine them. Figure A.5 and Table A.1 provide an illustration of when outfalls could be combined for assessment of soluble pollutants. Figure A.6 and Table A.2 provide an example of when outfalls could be combined for assessment of sediment-bound pollutants.

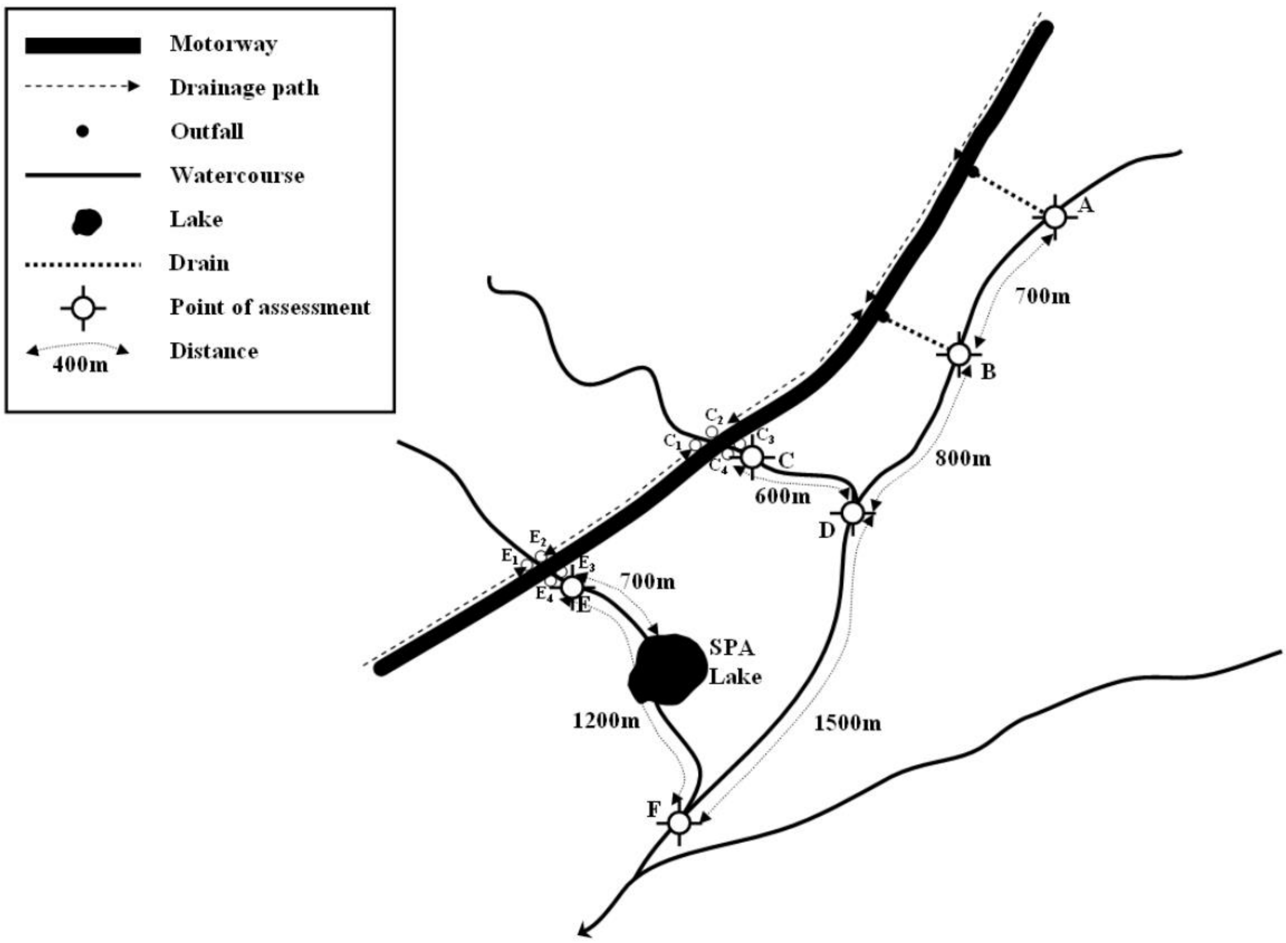


Figure A.5: Point of Assessment and Aggregation of Outfalls for Soluble Pollutants

Table A.1: Point of Assessment and Aggregation of Outfalls for Soluble Pollutants

Point of Assessment	Individual assessment(s) required?	Combined assessment required?	Notes
A	Yes	Yes A + B (but at B)	Individual assessment at A. Combined assessment at B as below.
B	Yes	Yes A + B	Individual assessment plus combined assessment for A + B (outfalls in same reach and within 1 km).
C	Yes C_1, C_2, C_3, C_4	Yes $C_1 + C_2 + C_3 + C_4$	The four outfalls on either side of the road and watercourse should first be assessed individually and then combined to identify cumulative risks.
D	n/a	Optional A + B + C	Assessment is optional as outfall A and B and outfall C discharge into different reaches and there is no direct discharge into the reach between point D and F. The need for an assessment should be based on local environmental considerations and consultation with the EPA, IFI or NPWS as appropriate. If required, this might include a combined assessment for A, B and C.
E	Yes E_1, E_2, E_3, E_4	Yes $E_1 + E_2 + E_3 + E_4$	The four outfalls on either side of the road and watercourse should first be assessed individually and then combined to identify cumulative risks. The discharge reaches a protected area within 1 km and this should be reflected in the assessments.
F	n/a	No	No assessment required. Point F is within a different reach.

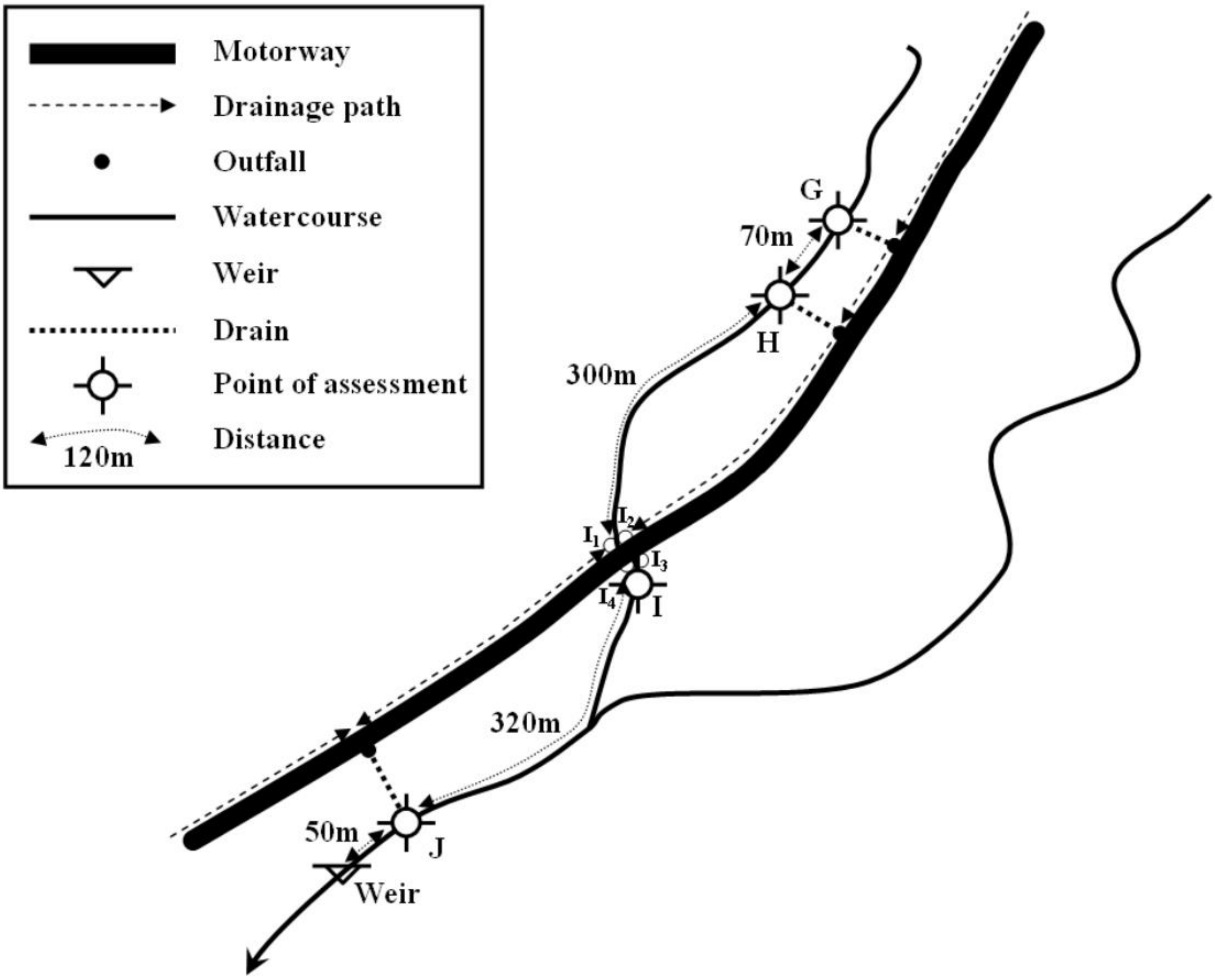


Figure A.6: Point of Assessment and Aggregation of Outfalls for Sediment-Bound Pollutants

Table A.2: Point of Assessment and Aggregation of Outfalls for Sediment-Bound Pollutants

Point of Assessment	Individual assessment(s) required?	Combined assessment required?	Notes
G	Yes	Yes G + H (but at H)	Individual assessment at G. Combined assessment at H as below.
H	Yes	Yes G + H	Individual assessment plus combined assessment for G + H (outfalls in same reach and within 100 m).
I	Yes I_1, I_2, I_3, I_4	Yes $I_1 + I_2 + I_3 + I_4$	The four outfalls on either side of the road and watercourse should first be assessed individually and then combined to identify cumulative risks.
J	Yes	No	Individual assessment only. A downstream structure (weir) lies within 100 m of the discharge point. This should be reflected in the assessment as the structure may cause sediment to accumulate.

A.17. Where a cumulative assessment for a proposed project or an existing situation identifies a potential environmental risk the procedure should be to first identify which, if any, individual outfall(s) fails the assessment. This failing outfall(s) should then be re-evaluated with mitigation applied (in HAWRAT) and then re-assessed cumulatively. In determining which individual outfall(s) fails the assessment it is useful to remember that, when all others parameters are equal, the outfall draining the largest impermeable road area will be the most likely to fail the assessment.

Interpretation of HAWRAT for Purposes of Mitigation

A.18. When outfalls fail the Method A and B assessments for likely impacts from routine runoff, HAWRAT provides an indication of the scale of mitigation required. To reduce the impacts from soluble pollutants there are two options for mitigation: limiting the discharge rate (thereby increasing the dilution) and/or treating the runoff to reduce the concentration of soluble pollutants reaching the watercourse. The degree of flow attenuation and/or treatment required can be investigated iteratively using Step 3 of HAWRAT. If this exercise determines that, for example, a maximum discharge rate of ‘5 l/s’ is required, the drainage system would need to be designed to restrict the discharge rate to 5 l/s. Exceeding this discharge rate could result in inadequate dilution in the watercourse and an exceedance of the toxicological thresholds (the RSTs). The percentage of treatment required indicates the percentage by which the concentrations of soluble pollutants in the runoff will need to be reduced in order to achieve compliance with the toxicological thresholds. The treatment percentages given by HAWRAT are very precise, however, current best practice does not provide precise, accurate or robust treatment efficiencies for the available treatment options. Therefore, a degree of pragmatism will be required when designing a drainage system to meet the required treatment percentages. The treatment train should be sufficient to reasonably treat the runoff.

A.19. If Method B reports a failure of the EQSs it is likely that the RSTs are also being exceeded. It is also likely that a lesser degree of treatment is required to comply with the EQSs than for the RSTs. The designer should aim to achieve compliance with both EQSs and RSTs but at sites where this is difficult the design should at least provide sufficient treatment to comply with the EQSs. In considering mitigation options, it should be noted that flow attenuation will not reduce annual average concentrations (against which EQS compliance is measured) as all the runoff will eventually reach the river within the year.

A.20. For impacts associated with sediment-bound pollutants, HAWRAT indicates the degree of settlement required in order to reduce the extent of deposition to an acceptable level. For example, '18% settlement needed' requires that the volume of sediment in the runoff needs to be reduced by 18% before discharge to the watercourse. As with the treatment of soluble pollutants, the percentages given by HAWRAT are very precise but current best practice does not provide precise, accurate or robust settlement efficiencies for the available settlement options and a degree of pragmatism will be required.

Method B – Detailed Assessment

B.1 If in-river annual average concentrations of soluble pollutants exceed the EQSs there may be a need to assess the bioavailability of the soluble pollutants in exceptional circumstances. One reason that the need for a bioavailability assessment will be exceptional is that if annual average concentrations exceed EQSs it is likely that the RSTs are also being exceeded. Treatment of soluble pollutants to meet the RSTs will also reduce the annual average concentrations and may result in compliance with the EQSs without need for a bioavailability assessment. Note that mitigation through flow attenuation will not reduce annual average concentrations as all the road-derived runoff will continue to reach the river in the course of a year.

B.2 The toxicity of soluble pollutants depends on their availability to exposed organisms. Metals will bind to Dissolved Organic Carbon (DOC) and thereby become unavailable to aquatic organisms. In general, the greater the DOC the lower the bioavailability. The degree of binding is modified by other parameters such as pH and hardness. EQSs are not site-specific and do not account for bioavailability. Following the procedures illustrated in Figure A.4, there are two tiers of assessment for copper (but only one for zinc). The first, and more simple assessment, requires the following inputs:

a) predicted in-river concentrations of dissolved copper and dissolved zinc (from HAWRAT);

b) pH;

c) water hardness (as Ca) of watercourse; and

d) DOC concentration of watercourse.

B.3 To establish the values of these parameters with sufficient confidence a series of samples will be required from the watercourse at the point of assessment. As a general guide, at least five water samples spread over a six month period will be required. However, existing data may be used if DOC and pH show little variation over time. The sample analysis results should be run through the assessment to determine whether there is likely to be an impact.

B.4 The simple assessment for copper is precautionary and does not consider all the mitigating factors. Consequently, if the result indicates that there may be an impact, it will be necessary to run a more detailed assessment (Figure A.4). In addition to the inputs listed above, the following watercourse parameters are required for a detailed assessment:

a) temperature;

b) magnesium;

c) sodium;

d) potassium;

e) sulphate;

f) chloride; and

g) alkalinity.

As with the simple assessment, at least five water samples spread over a six month period will be required. It is advised that all parameters are included in the original analyses so that the sampling procedure does not need to be repeated if a detailed assessment is required.

B.5 Following the procedure in Figure A.4, if the bioavailability tests show that no ecological impact is expected then no further action need be taken with respect to annual average concentrations. If an impact is predicted then mitigation should be considered. Mitigation can be included in HAWRAT at Step 3 (refer to paragraphs A.19 to A.21 for further information). The post-mitigation annual average concentrations of copper and zinc can then be re-run through the procedure shown in Figure A.4. Once both Method A and Method B assessments have been completed, Table 5.2 should be consulted for advice on how to proceed.

METHOD C – GROUNDWATER PROTECTION RESPONSE FOR THE USE OF PERMEABLE DRAIN SYSTEMS ON ROAD SCHEMES

Background

C.1 Groundwater in Ireland is protected under European Union and national legislation. Local authorities and the Environmental Protection Agency (EPA) have responsibility for enforcing this legislation. The Geological Survey of Ireland (GSI) in conjunction with the Department of Environment, Community and Local Government (DECLG) (formerly the Deparment of Environment and Local Government, DELG) and the EPA have developed a methodology for the preparation of groundwater protection schemes to assist the statutory authorities and others to meet their responsibility to protect groundwater (DELG/EPA/GSI, 1999). This methodology incorporates land surface zoning and groundwater protection responses.

These groundwater protection responses are concerned with routine runoff from roads and do not deal with spillages.

The risk to groundwater from road runoff is mainly influenced by:

a) Hydraulic and contaminant load. This will be a function of the rainfall, traffic count and contaminants expected.

b) The infiltration capacity of the subsoil. This will determine whether, and how fast, the soil will drain or whether ponding will occur.

c) The thickness, permeability and moisture content of the unsaturated zone. The thickness of the unsaturated zone will be a function of the depth to the water table and whether the drainage is at grade, in a cut or in fill. The vertical permeability of the unsaturated zone will influence the infiltration capacity.

d) The thickness and porosity of the saturated subsoil.

e) The presence or lack of weathered bedrock.

f) The attenuation capacity of the subsoil.

g) Groundwater flow mechanisms i.e. whether horizontal flow is intergranular or fracture flow.

C.2 The topsoil and subsoil, depending on their type, permeability and thickness, play a critical role in preventing groundwater contamination and mitigating the impact of many potential pollutants. They act as a protecting filtering layer over groundwater. The vulnerability of the groundwater is the most important factor in deciding on the control measures for any area. It should be noted however, that in areas classed as 'Low Vulnerability' (thick deposits of low permeability subsoils) there may be an increased risk to surface waters due to run-off, which should be addressed in the drainage design.

C.3 In general the pollution risk is greater near groundwater abstraction sources, in particular within the Inner Protection Area.

C.4 Guidance presented in this document is based on the precautionary principle. This guidance should be used to assist in the design of road drainage and the decision as to whether impermeable drainage systems are required to protect groundwater. Each road design will be unique and should take local site specific factors into account in applying the responses.

C.5 If the assessment is undertaken and determines that permeable drainage is not suitable, mitigation measures can be designed and incorporated into the proposed design. The GPR assessment should be undertaken again at this stage, this time considering the proposed mitigation measures. The stages of the assessment, including any iterations of the assessment to include mitigation measures, should be fully documented.

C.6 These groundwater protection responses should be read in conjunction with Groundwater Protection Schemes (DELG/EPA/GSI, 1999).

Routine runoff from roads: a Potential Hazard for Groundwater

C.6 A broad range of potential pollutants is associated with routine runoff from operational roads. These are combustion products of hydrocarbons, fuel and fuel additives, catalytic converter materials, metal from friction and corrosion of vehicle parts, lubricants, and materials spread during gritting and de-icing. Particulate contaminants originating from vehicles and vehicle related activities include carbon, rubber, plastics, grit, rust and metal filings.

C.7 Most organic compounds have very low solubility in water. Such compounds can occur in routine runoff and include a wide range of polycyclic aromatic hydrocarbons (PAHs). Other materials may be deposited on road surfaces such as wind blown soils from adjacent land.

C.8 Studies referenced by the UK Highways Agency (HA) show that routine road runoff contains both dissolved and particulate contaminants. A large number of studies have investigated the concentrations of contaminants in road runoff. These studies have investigated a variety of road types in a number of countries. Research into the concentrations of contaminants in road runoff shows a large variation in concentrations of those contaminants detected. Applied road salt may also enhance the release of toxic metals from silts and sludge.

C.9 The UK HA has undertaken collaborative research in England with the Environment Agency (EA) to significantly improve the reliability and extent of existing data for pollutants and their concentrations found in road runoff from non-urban trunk roads and motorways. The results were used to identify a list of significant pollutants that are routinely found in road runoff and which pose a risk of short-term acute impacts (from soluble pollutants) and/or long-term chronic impacts (from sediment-bound pollutants) on ecosystems. The study also identified those site characteristics that influence pollutant concentrations.

Table A.3: Summary of EMCs and Loads from in road runoff for Significant Pollutants (UK HD 45/09)

Determinand	Runoff Concentration						Runoff Load	
	Units	LOD	Min. EMC	Mean EMC	Median EMC	Max. EMC	Mean/ 1000m²	Units
Total Copper	µg/l	0.3	4.00	91.22	42.99	876.80	0.66	g
Dissolved Copper	µg/l	0.3	2.15	31.31	23.30	304.00	0.16	g
Total Zinc	µg/l	0.6	9.73	352.63	140.00	3510.00	2.44	g
Dissolved Zinc	µg/l	0.6	4.99	111.09	58.27	1360.00	0.50	g
Total Cadmium	µg/l	0.01	<0.01	0.63	0.29	5.40	0.00	g
Total Fluoranthene	µg/l	0.01	<0.01	1.02	0.30	12.50	0.01	g
Total Pyrene	µg/l	0.01	<0.01	1.03	0.31	12.50	0.01	g
Total PAHs (Total)	µg/l	0.01	<0.01	7.52	3.33	62.18	0.04	g

LOD = Analytical limit of detection

Groundwater Protection Response Matrix for the use of permeable drain systems on Road schemes

C.10 The reader is referred to the full text in Groundwater Protection Schemes (DELG/EPA/GSI, 1999) for an explanation of the role of groundwater protection responses in a groundwater protection scheme.

C.11 The role of the groundwater response matrix is to provide an initial evaluation of the general suitability of a permeable drainage system for National Road schemes. This should be carried out for each drainage catchment to determine the requirements for impermeable drainage systems. It takes account of the resource protection area, the Source Protection Area (SPA) and the vulnerability of the groundwater.

C.12 A permeable drainage system, for the purposes of this assessment, is one that allows infiltration of surface water runoff to ground.

C.13 A risk assessment approach is taken in the development of this response matrix. A precautionary approach is taken because of the variability of Irish subsoils and bedrock.

C.14 Prior to proceeding to the response matrix, if a permeable drainage system is being considered the following points should be investigated to confirm they won't preclude the use of a permeable system:

a) Is the ground capable of accepting infiltration? This should be confirmed through site specific testing.

b) Is there a risk of groundwater flooding?

c) Is there the risk of karst reactivation through discharges to ground?

C.15 The appropriate response to the risk of groundwater contamination is given by the assigned response category (R) appropriate to each protection area (Refer to Table A.4). Individual design responses are assigned based on the risk to groundwater resources. The risk to groundwater resources is determined based on the following criteria:

a) **Aquifer category:** subdivides areas according to the value of the groundwater resources or aquifer category. This can be used to identify karst or high resource value aquifers. The GSI aquifer maps (bedrock and gravel) should be used to determine the resource protection area. If a gravel aquifer is present, the requirements for the protection of this aquifer will supersede those for the protection of the bedrock aquifer beneath it.

b) **Groundwater vulnerability**: subdivides the entire land surface according to the vulnerability of the underlying groundwater to contamination and is based on the thickness and permeability of the overburden above the aquifer. The groundwater vulnerability should be determined on a site specific basis based on the ground investigation information available. The appropriate vulnerability should be calculated based on the criteria for a bedrock or gravel aquifer outlined in Groundwater Protection Schemes (DELG/EPA/GSI, 1999). The invert level of the drain is the point of discharge and this should be used as the criteria to determine the vulnerability, not the existing ground level.

c) **Source Protection Areas:** delineates areas contributing to public groundwater supplies and will identify the location of important resources such as public and group supply sources. Source Protection Areas (SPA) are divided into the Inner Protection Area (SI) and Outer Protection Area (SO) based on the travel time for any potential contamination, however this assessment considers the SPA as a whole, with the same protection criteria applied to the SO and SI. The GSI and EPA mapping tools define 'Drinking Water Protection Areas' and these should be consulted to determine the extents of the Inner and Outer Protection Areas.

C.16 A series of notes have been developed to accompany the matrix in Table A.4 which apply in all situations. These are as follows:

Note 1: The assessment methodology should considered as a Screening tool and be undertaken at the Design (Phase 3 of the NRA PMG) and environmental assessment (Phase 4 of the NRA PMG) phases of a project based on the information available at that time. It should be refined during Phases 5 and 6 (NRA PMG) if more information becomes available. Where relevant, a site specific risk assessment undertaken by qualified groundwater professional may superceed the requirements of this assessment. In these cases the assessment methodology followed should be fully outlined, the raw data provided and any interpretation of the data should be clearly explained.

Note 2: The vulnerability rating should be determined on a site specific basis based on the material below the invert level of the point of discharge to ground. Information on this material should be obtained from ground investigations and may be reassessed as more information becomes available.

Note 3: The matrix responses refer to "Appropriate material": This material may be natural in-situ material which should be unsorted, have a minimum of 10% total fines and less than 13% clay content, have a post compaction infiltration rate ranging from $5x10^{-5}$ to $5x10^{-7}$ m/s and be classed (using BS5930) as either; silty SAND, sandy SILT or SILT/CLAY. If the designer/contractor proposes to use reworked or process material to fulfil the requirements of the unsaturated zone, full details must be submitted to the NRA for approval prior to use.

Note 4: Cuts into rock will require impermeable drainage systems OR the placement of material in line with Note 3 beneath the invert level of the drain. Where the drainage system in a rock cut is being used to lower the water table to prevent groundwater discharging into the cut (the road), a separate impermeable or closed system must be designed to deal with the surface runoff.

Note 5: Where over the edge drainage is being used on permeable embankments over 1m high, the GPR assessment based on the invert level of the discharge point, is a conservative assessment. In these scenarios, if the designer wishes to use a permeable system where the response from the GPR is recommending an impermeable system, the designer must demonstrate that there is no risk to groundwater at that location.

Table A.4: Groundwater Protection Response Matrix for the use of permeable drains in road schemes

Vulnerability rating	Source protection area	Resource protection area (aquifer category)							
		Regionally Important Aquifer			Locally Important Aquifer			Poor aquifer	
		Rk*	Rf	Rg	Lg	Lm	Ll	Pl	Pu
Extreme: Rock near Surface or karst (X)	R4	R4	R4	R3(2)	R3(2)	R3(1)	R3(1)	R3(1)	R3(1)
Extreme (E)	R4	R2 (3)	R2 (2)	R3(2)	R3(2)	R2 (2)	R2 (2)	R2 (1)	R2 (1)
High (H)	R3(2)	R2 (2)	R2 (2)	R2(2)	R2(2)	R2 (2)	R2 (2)	R2 (1)	R2 (1)
Moderate (M)	R3(1)	R2 (1)	R2 (1)			R2 (1)	R2 (1)	R1	R1
Low (L)	R3(1)	R1	R1			R1	R1	R1	R1

* A small proportion of the country (~0.6%) is underlain by locally important karstic aquifers (Lk); in these areas, the groundwater protection responses for the Rk groundwater protection zone shall apply.

R1	Acceptable subject to minimum design standards in the NRA DMRB and Notes 1 and 2.
R2	
R2(1)	Acceptable subject to minimum design standards in the NRA DMRB and to meeting the following requirements : 1. There is a consistent minimum thickness of 1 m unsaturated subsoil, or 2 m in areas of karstified rock (Rk & Lk), beneath the invert level of the drainage system (Note 1). 2. During all stages of design particular attention must be paid to the presence of karst features and additional assessments undertaken if required. If karst features are identified response R2 (3) must be applied as a minimum. 3. During all stages of design particular attention must be paid to receptors (such as; public wells, group schemes, industrial water supply sources and springs) and additional assessments undertaken if required.

R2(2)	Acceptable subject to minimum design standards in the NRA DMRB, meeting requirements 1, 2 and 3 of above and the following additional requirements: 4. Where the subsoil is classed using BS5930 as; SAND, GRAVEL or SILT (in circumstances where the clay content is <10%) AND/OR is underlain by limestone bedrock, there is a consistent minimum thickness of 2 m unsaturated subsoil beneath the invert level of the drainage system. OR There is a minimum consistent unsaturated thickness 1m of "appropriate material" (Note 3) either natural or man-made beneath the invert level of the point of discharge. 5. Where a gravel aquifer is present, a consistent minimum thickness of 3 m unsaturated subsoil beneath the invert level of the drainage system must be present.
R2(3)	Acceptable subject to minimum design standards in NRA DMRB, meeting requirements 1, 2, 3, 4 and 5 above and the following additional requirements: 6. The drainage system shall be at least 15m away from karst features that indicate enhanced zones of high bedrock permeability (e.g. swallow holes and dolines (collapse features)). 7. The site investigation shall pay particular attention to the possibility of instability in these karst areas.
R3	
R3(1)	Not generally acceptable, unless requirements 1, 2, 3 and 4 and the following additional requirements are met: 8. If discharge to surface water is not possible then additional assessments by an appropriately qualified groundwater specialist are required to determine the risk to groundwater resources (the aquifer).

R3(2)	Not generally acceptable, unless requirements 1, 2, 3, 4, 5 (in karst areas), 6 (in karst areas), 7 and 8 and the following additional requirements are met: 9. A risk assessment undertaken by a qualified hydrogeologist demonstrates that there will be no significant impact to groundwater or receptors. AND 10. A treatment system which treats pollutants through filtration, sedimentation, absorption etc should be incorporated into the system prior to discharge.
R4	Not acceptable.

METHOD D – ASSESSMENT OF POLLUTION IMPACTS FROM SPILLAGES

D.1 This method provides an indication of the risk of a spillage causing a pollution impact on receiving water bodies.

D.2 This risk is defined as the probability that there will be a spillage of pollutant and that the pollutant will reach and impact the water body to such an extent that either a Category 1 or 2 incident – a serious pollution incident – occurs. Table A.5 defines these categories. The probability is the product of two separate risks:

a) the probability that there will be a spillage with the potential to cause a serious pollution incident; and

b) the probability, assuming such a spillage has occurred, that the pollutant will cause a serious pollution incident.

D.3 The risk is expressed as the probability of an incident in any one year. It is initially assessed without any mitigation measures. If mitigation measures are needed, the risk is reduced by the pollution risk reduction factor for each measure given in Table 8.1.

D.4 In most circumstances, the acceptable risk of a serious pollution incident occurring will be where the annual probability is predicted to be less than 1%. In cases where, for example, road runoff discharges within close proximity to (i.e. within 1km) a natural wetland or designated wetlands, such as SACs and SPAs, or it could affect important drinking water supplies or other important abstractions, a higher standard of protection will be required such that the risk of a serious pollution incident has an annual probability of less than 0.5%. In such cases, advice is to be sought from the EPA, IFI and NPWS.

D.5 To determine the risk, the following data are required for each reach or section of aquifer into which runoff is to be discharged:

a) the length of road in each of the categories in Table A.5;

b) the AADT two way flow for each section of road, other than slip roads, identified above (for new roads, use the design year traffic flow); and

c) the percentage of the AADT flow that comprises Heavy Goods Vehicles (HGVs) (where roads are known to carry an unusually high proportion of hazardous materials, for example to an oil refinery or creamery, a higher factor may be appropriate).

D.6 HAWRAT (described in Method A) incorporates a spreadsheet which uses these data to automate the calculation of spillage risk and the probability of a serious pollution incident. It is recommended that before using HAWRAT to calculate spillage risk the assessor should be familiar with the manual calculations which are described below.

D.7 Using these data, calculate the annual probability of a spillage for each section of road, using the following formula:

$P_{SPL} = RL \times SS \times (AADT \times 365 \times 10^{-9}) \times (\%HGV/100)$

Where:

P_{SPL} = annual probability of a spillage with the potential to cause a serious pollution incident

RL = road length in kilometres

SS = spillage rates from Table A.5

AADT = annual average daily traffic (use design year for new road)

%HGV = percentage of heavy goods vehicles

D.8 Calculate the predicted annual probability of a serious pollution incident for each section of road, using this formula:

$P_{INC} = P_{SPL} \times P_{POL}$

Where:

P_{INC} = the probability of a spillage with an associated risk of a serious pollution incident occurring

P_{POL} = the probability, given a spillage, that a serious pollution incident will result. An appropriate value for this is to be selected from Table A.6. This will depend on the sensitivity of the water course and how soon it can be reached by the emergency services.

D.9 Add the annual probabilities for each section of road draining into a reach. If this figure is greater than the acceptable risk, repeat the above steps for each individual outfall, to determine the risk from each outfall.

D.10 Select the discharge with the highest individual risk, and consider whether any of the factors can be amended, or if the outfall can be relocated, or if a form of mitigation can be included. Recalculate the risk using the appropriate risk reduction factor for the measure selected. Chapter 8 gives factors to be used.

D.11 Recalculate the overall risk to each reach by adding all the revised individual outfall risks. Where necessary mitigation measures are to be included at other outfalls, until an acceptable overall risk for each reach is achieved.

D.12 In some (rare) instances, two forms of mitigation may be required to reduce the probability to an acceptable level of risk. Where this occurs, the two forms of mitigation should be complementary and should not rely on the same mechanisms for their effect. At least one should be a passive system, as described in Chapter 8.

Table A.5 – Serious Spillages in Billion HGV km/year

	Motorways	Rural National Roads	Urban National Roads
No Junction	0	0.29	0.31
Slip Road	0	0.83	0.36
Roundabout	3	3.09	5.35
Crossroad		0.88	1.46
Side Road		0.93	1.81
Total	**0**	**0.45**	**0.85**

The risk factor applies to all road lengths within 100 m of these junction types. So for a side road joining an urban National Road the factor is 1.81 for 100 m of the side road and for a 200 m length of the main road, centred on the junction.

Table A.6 – Probability of a Serious Pollution Incident Occurring as a Result of a Serious Spillage

Receiving water body	Urban (response time to site <20 minutes)	Rural (response time to site <1 hour)	Remote (response time to site >1 hour)
Surface watercourse	0.45	0.6	0.75
Groundwater	0.3	0.3	0.5

METHOD E – HYDROLOGICAL ASSESSMENT OF DESIGN FLOODS

E.1 A range of methodologies is available for calculating flood flows of differing return periods. In the context of National Roads projects there are two overlying sources of information for hydrologic requirements and flood estimation:

a) OPW – For all watercourses under the remit of the OPW (as explained in NRA HD 106) reference should be made to www.opw.ie/en/floodriskmanagement/ and Section 50 guidelines for information and requirements regarding flood risk and construction or alteration of watercourse infrastructure. Also refer to www.floodmaps.ie and www.cfram.ie/pfra for information regarding flood risk and to www.opw.ie/en/fsu/ for flood estimation.

b) NRA – For all other watercourses (generally minor watercourses or ditches as explained in NRA HD 106) the NRA requirements of NRA HD 106 and NRA HD 107 shall apply.

METHOD F – HYDRAULIC ASSESSMENT

F.1 If modelled or observed flood levels and extents are not available for the river reach affected by a watercourse it will be necessary to construct a hydraulic model using the flood flows derived in the hydrological analysis (described in the previous section). Hydraulic models may be mathematical or physical, depending on the complexity of the watercourse at the point of interest. It is usual to use mathematical models as physical models are expensive and do not lend themselves to the examination of a range of options. A range of models can be constructed and they may be one or two dimensional, with steady or unsteady flows. In most cases it will be sufficient to construct a one-dimensional model using a suitable hydraulic software package.

Data Input

F.2 The river reach is modelled using a series of cross-sections with associated storage areas, overflows, structures, etc. The choice of energy loss coefficients is fundamental to the validity of the modelled results. Advice on the correct use of coefficients can be found in textbooks, such as Open Channel Hydraulics and Handbook of Hydraulics and should be discussed in advance with the OPW to avoid wasted work using inappropriate coefficients. The upstream and downstream model extents, defining the maximum area within the floodplain that could be affected by the scheme, should also be agreed with the OPW.

Calibration and Validation

F.3 The calibration of a hydraulic model involves obtaining water levels for a recorded flood event of known peak flow, and adjusting the model coefficients to obtain a reasonable fit. Therefore, observed water levels and corresponding flow are required for calibration purposes. Recent major floods, such as the events of 2009, have been recorded and documented by the OPW with many major rivers having a flood extent outline map, and gauged estimates of flow. Low flow conditions are not appropriate for calibration because the values of coefficients vary with river stage.

F.4 It is recommended that the model is calibrated on three or more recorded flood events if possible, and then validated on another, with particular attention being paid to the incidence of blockage. If no calibration data is available for the study site then rigorous sensitivity testing should be undertaken to fully quantify the uncertainties within the model.

Sensitivity Testing

F.5 After a model has been calibrated, a series of sensitivity tests should be carried out in order to determine the models sensitivity to the coefficients and parameters used. For example:

a) by sensitivity testing the roughness coefficient, the analyst can see how the water level would be affected by different types of vegetation and thus be able to assess seasonal variations;

b) by considering the effects of full or partial blockage of components of a structure, and any resultant increased flood envelope;

c) by considering the transition details between open channel and structure, to optimise their conveyance of flow into and out of the structure;

d) testing for the effects of climate change on design flows.

F.7 Where the effects of a road crossing on an adjacent watercourse need to be determined, it is recommended that the methodology be agreed with the OPW prior to any calculations being undertaken. Figure A.7 indicates the procedure for undertaking the assessment.

F.8 In order to determine the effect of a road or bridge the following tasks should be undertaken:

a) contact the OPW to agree a methodology and collect any available flood data;

b) either update an existing model, if available or construct a new site-specific model;

c) determine if the model requires a time dependent input, e.g. for assessment of storage volumes;

d) apply the proposal to the model, to determine the loss of floodplain storage and effects on upstream and downstream water levels;

e) if the model indicates that the afflux is unacceptable, redesign the proposal to achieve an acceptable impact.

F.9 Guidance on the requirements of hydraulic modelling is available from the OPW website (www.opw.ie/en/floodriskmanagement/) and is therefore not restated within this guidance note. The hydraulic modelling packages also have accompanying detailed hydraulic manuals, which provide guidance on the parameterisation, calibration and sensitivity testing that should be carried out.

F.10 As with all models where limited calibration and validation data is available, the results should be treated with caution. The effects of climate change should be considered.

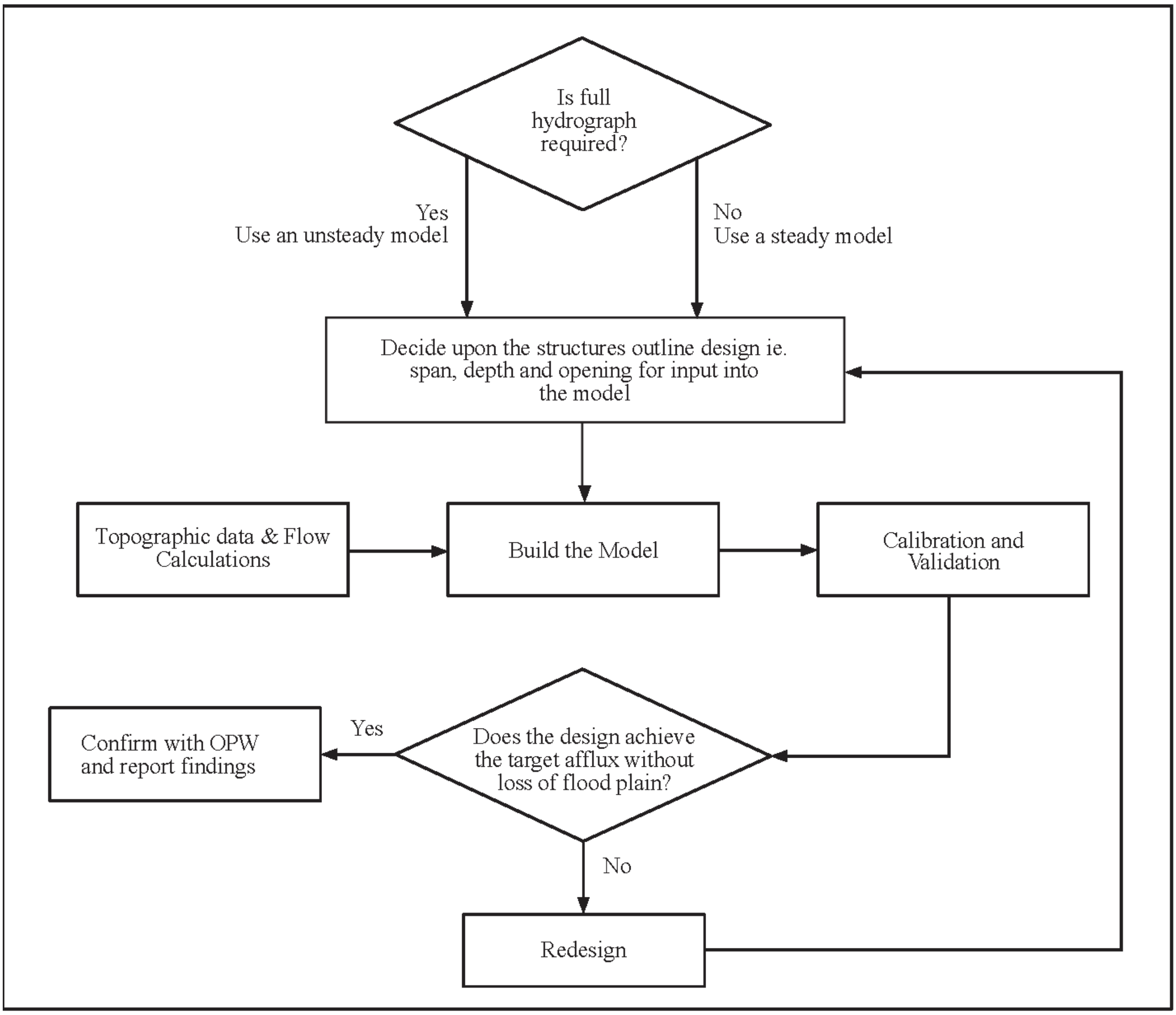


Figure A.7: Flowchart for Hydraulic Design

APPENDIX B: REPORTING OF SIGNIFICANCE OF POTENIAL EFFECTS

When reporting the potential effects of a road project, NRA's Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes should be used as supported by the results of the assessment methods together with other technical and qualitative information sufficient to provide a transparent decision-making process.

Table B.1: Summary of Potential Effects – Water Environment

Summary of all potential impacts and their significance

Potential Impact	Feature	Attribute	Quality	Importance	Mitigation	Magnitude	Significance

Reference Sources:

Other qualitative comments:

APPENDIX C: WORKED EXAMPLES

For each of the worked examples in this appendix, the significance of the associated potential effects has been recorded in Table C.7 (at the end of this appendix) according to the procedures described in the NRA's Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes. Table C.7 is a completed version of the template Table B.1 (Appendix B).

Assessment of Pollution Impacts from Routine Runoff to Surface Waters

METHOD A

Worked Examples

Example A1

A motorway is being widened from dual two to dual three lanes, including hard shoulders. The completed motorway will be 28 m wide. A 2km length of the road drains to a reach of a small good quality river. The stream is used for recreational fishing. The following data apply:

Data for Step 1 – Runoff quality:

AADT for two-way flow	115,000 vehicles/day (expected future flow)
Climatic region	Colder-wet
Rainfall site	830mm

Data for Step 2 – River impacts:

95%ile river flow (Q_{95})	0.15 m^3/s
Base flow index	0.6
Impermeable road area drained	5.6ha (2,000m × 28m/10,000)
Permeable area draining to outfall	2.2ha
Is the discharge in or within 1km upstream of a protected site for conservation?	No
Water hardness	230mg $CaCO_3$/l
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100 m downstream of the point of discharge?	No
Tier 1, Estimated river width	4m

Initially a Step 1 assessment is carried out. For a Step 1 assessment to work, the 95%ile river flow (Q_{95}) has to be set to zero. The Annual Average Daily Traffic (AADT), climatic region and rainfall site should be selected from the ranges in HAWRAT and the 'Predict Impact' button clicked. In this example, once the tool has completed the calculations, the user interface displays red 'fail' boxes for each of the soluble pollutants and sediment-bound pollutants in the runoff, i.e. the runoff concentrations exceed the toxicity thresholds. A Step 2, river impact, assessment is therefore needed.

The Step 2 data given above are entered into HAWRAT, including the Q_{95} of 0.15m^3/s, and the 'Predict Impact' button is clicked. The user interface should appear as in Figure C.1. The detailed results sheet should appear as in Figure C.2. It can be seen that each of the soluble pollutants and the sediment-bound pollutants pass the Step 2 assessment. The site is non-accumulating as the low flow velocity is 0.13m/s (i.e. above the depositing threshold of 0.1m/s).

To complete the risk assessment the annual average concentrations of dissolved copper and zinc need to be compared with the EQS values. HAWRAT displays the annual average concentration on the user interface. In this example, at Step 2, the annual average copper and zinc concentrations are 0.07µg/l and 0.36µg/l respectively.

Both the HAWRAT assessment and the comparison with EQSs give a 'pass'. Table 5.2 shows that no further assessment is required i.e. there is not considered to be a potential for adverse ecological impacts in the receiving river.

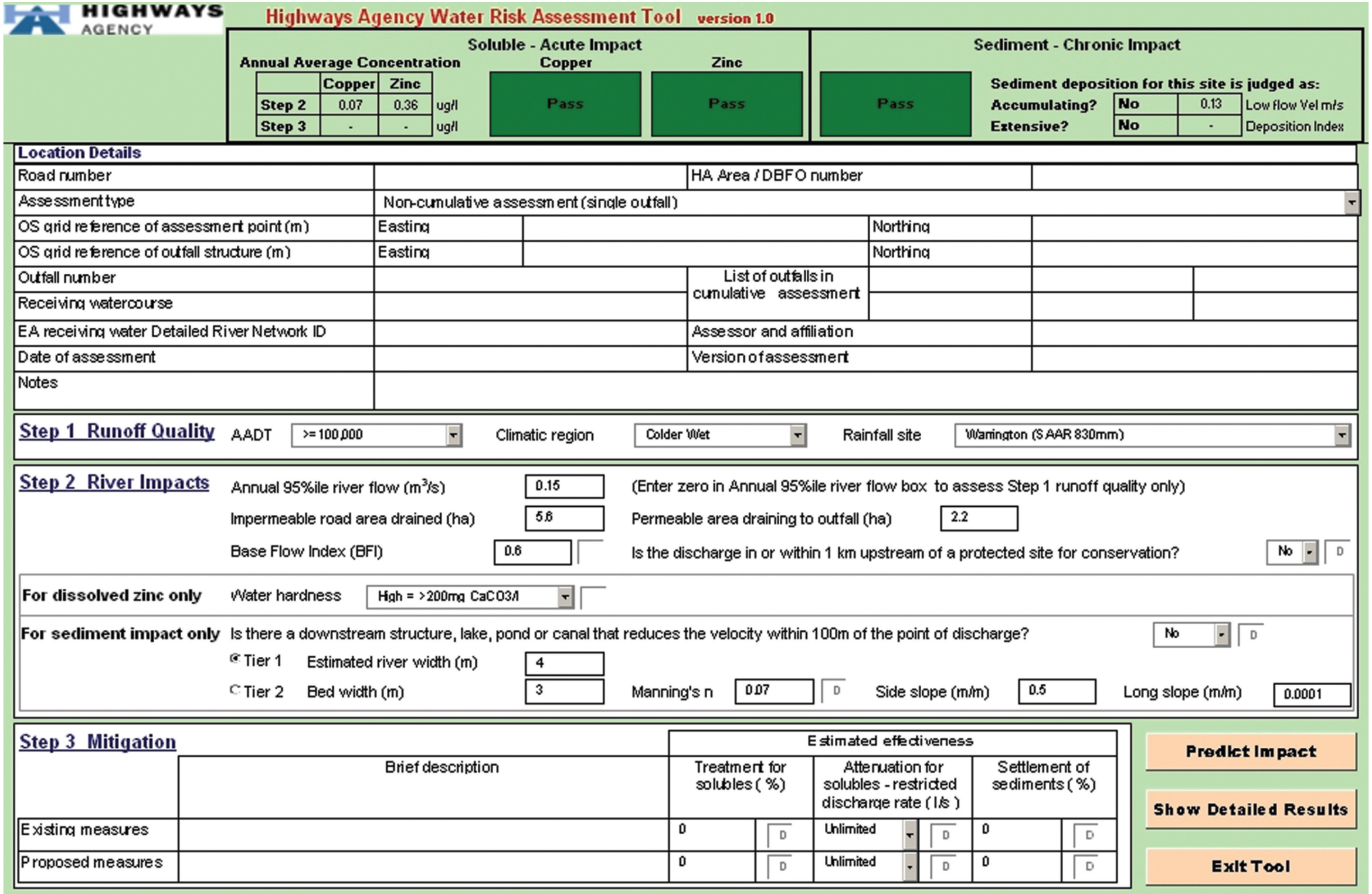


Figure C.1: HA WRAT User Interface After Running Step 2, Tier 1 Calculations for Worked Example 1

Summary of predictions

	Soluble - Acute Impact		Sediment - Chronic Impact							
	Copper	Zinc	Copper	Zinc	Cadmium	Total PAH	Pyrene	Fluoranthene	Anthracene	Phenanthrene
Prediction of impact Step1										
Step2										
Step3										

DETAILED RESULTS

In Runoff

Step 1 (Soluble)

	Copper	Zinc
RST24		
Allowable Exceedances/year	1	1
No. of exceedances/year	70.70	75.80
No. of exceedances/worst year	82	86
RST6		
Allowable Exceedances/year	1	1
No. of exceedances/year	39.30	54.70
No. of exceedances/worst year	51	65
	(ug/l)	(ug/l)
Thresholds RST24	21	385
Thresholds RST6	42	770
Event Statistics Mean	48.21	214.66
90%ile	91.86	444.70
95%ile	124.22	619.82
99%ile	188.59	1102.82

Step 1 (Sediment)

	Copper	Zinc	Cadmium	Total PAH	Pyrene	Fluoranthene	Anthracene	Phenanthrene
Toxicity Threshold								
Allowable Exceedances/year	1	1	1	1	1	1	1	1
No. of exceedances/year	77.60	85.80	3.80	28.10	67.70	28.10	13.50	55.60
No. of exceedances/worst year	90	99	9	38	83	38	23	72
	(mg/kg)	(mg/kg)	(mg/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)	(ug/kg)
Toxicity	197	315	3.5	16770	875	2355	245	515
Event Statistics Mean	685	2646	1	15514	2684	2575	164	726
90%ile	1384	5695	3	28184	4876	4679	299	1319
95%ile	1733	7416	3	35481	6138	5890	376	1661
99%ile	2268	11124	5	89125	15419	14795	945	4171

In River (no mitigation)

Step 2

	Copper	Zinc
RST24		
Allowable Exceedances/year	2	2
No. of exceedances/year	0	0
No. of exceedances/worst year	0	0
No. of exceedances/summer	0	0
No. of exceedances/worst summer	0	0
RST6		
Allowable Exceedances/year	1	1
No. of exceedances/year	0	0
No. of exceedances/worst year	0	0
No. of exceedances/summer	0	0
No. of exceedances/worst summer	0	0
Annual average concentration (ug/l)	0.07	0.36
	(ug/l)	(ug/l)
Thresholds RST24	21	385
Thresholds RST6	42	770
Event Statistics Mean	0.37	1.58
90%ile	0.89	3.69
95%ile	1.40	6.81
99%ile	3.98	19.89

Step 2

Velocity 0.13 m/s — Tier 1 is used for the calculation

DI -

% settlement needed - %

In River (with mitigation)

Step 3

	Copper	Zinc
RST24		
Allowable Exceedances/year	2	2
No. of exceedances/year	-	-
No. of exceedances/worst year	-	-
No. of exceedances/summer	-	-
No. of exceedances/worst summer	-	-
RST6		
Allowable Exceedances/year	1	1
No. of exceedances/year	-	-
No. of exceedances/worst year	-	-
No. of exceedances/summer	-	-
No. of exceedances/worst summer	-	-
Annual average concentration (ug/l)	-	-
	(ug/l)	(ug/l)
Thresholds resholds RST24	21	385
Thresholds RST6	42	770
Event Statistics Mean	-	-
90%ile	-	-
95%ile	-	-
99%ile	-	-

DI -

Figure C.2: HAWRAT Detailed Results After Running Step 2, Tier 1 Calculations for Worked Example 1

Example A2

A dual three lane motorway is being upgraded. The construction of emergency refuge areas will increase the impermeable area of the carriageway that drains to a small stream of moderate quality. The following data apply:

Data for Step 1 – Runoff quality:

AADT	136,000 vehicles/day (expected future flow)
Climatic region	Warmer-wet
Rainfall site	820mm

Data for Step 2 – River impacts:

95%ile river flow (Q_{95})	$0.006m^3/s$
Base flow index	0.35
Impermeable road area drained	12.8ha
Permeable area draining to outfall	0.8ha
Is the discharge in or within 1km upstream of a protected site for conservation?	No
Water hardness	70mg $CaCO_3/l$
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100 m downstream of the point of discharge?	No
Tier 1, Estimated river width	1m

Using HAWRAT, a Step 1 assessment determines that runoff quality exceeds the toxicity thresholds for both soluble and sediment-bound pollutants. For a Step 2 assessment it can be seen that both the soluble pollutants (copper and zinc) fail the assessment. The site is accumulating (the low flow velocity of 0.05m/s is below the depositing threshold of 0.1m/s). The deposition index is 306 and is therefore greater than the threshold of 100. As a result, the sediment-bound pollutants fail the assessment. Following the logic chart (Figure A.3) and as prompted by HAWRAT, the next consideration for the sediments is to use Tier 2. To get the data required for Tier 2, a site visit was made to get the following data:

Bed width	1.3m
Manning's n	0.045
Side slope	1.09m/m
Long slope	0.022m/m

Following the Tier 2 assessment, HAWRAT predicts the low flow velocity will be 0.26m/s, i.e. a non-accumulating site, and there will be no adverse effect from sediment-bound pollutants. However, using Tier 2 does not affect soluble pollutants and the potential for adverse ecological impacts from soluble pollutants remains.

Before moving to Step 3 and investigating the scale of mitigation required, the annual average concentrations of dissolved copper and zinc should be compared with the EQSs. In this example, at Step 2, the annual average copper and zinc concentrations are 1.46µg/l and 8.02µg/l respectively. The zinc concentration is above the EQS threshold for water in this hardness band and the outfall fails the assessment.

Following the logic chart (Figure A.4), where the predicted annual average concentration exceeds the EQS, a Method B (detailed assessment) is required (see Method B Worked Example 1 below). However, if a proposed design exists which includes treatment (not just flow attenuation – paragraph A.12) then this will likely reduce the annual average concentrations and may bring them below the EQSs. The relevant advice in Table 5.2 will depend on the outcome of the Method B and/or Step 3 assessment.

For this worked example, interrogation of HAWRAT at Step 3 reveals that it is not possible to pass the HAWRAT assessment through flow attenuation (dilution) alone as the runoff would have to be discharged at a slower rate than it accumulates. Alternatively, without any dilution, a treatment system with a pollutant removal efficiency of more than 60% would be required for the outfall to pass. Such a treatment system would also reduce the annual average concentration and enable compliance with the EQSs. If a combination of dilution and treatment is used then, for example, 50% treatment and a restricted discharge rate of 4 l/s would be sufficient to pass.

In this worked example the mitigation required is considerable. This is perhaps not surprising given that the impermeable road area draining to the outfall is relatively large and the receiving watercourse is relatively small.

Example A3

A roundabout connecting a rural trunk road to a motorway is being upgraded to include filter lanes. Part of the slip road, roundabout and trunk road drains to a stream with a good ecological status (Fraser Stream). The stream is used for irrigation. Of the three road sections that drain to the stream the roundabout carries the greatest traffic load (78,000 vehicles/day). The following data apply:

Data for Step 1 – Runoff quality:

AADT	78,000 vehicles/day (expected future flow)
Climatic region	Colder-dry
Rainfall site	600mm

Data for Step 2 – River impacts:

95%ile river flow (Q_{95})	$0.03m^3/s$
Base flow index	0.5 (default value, actual value not available)
Impermeable road area drained	7.2ha
Permeable area draining to outfall	0ha (not available, use zero as precautionary)

Is the discharge in or within 1km upstream of a protected site for conservation?	No
Water hardness	286mg $CaCO_3$/l
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100 m downstream of the point of discharge?	No
Tier 1, Estimated river width	3.5m

Using HAWRAT, a Step 1 assessment determines that runoff quality exceeds the toxicity thresholds for both soluble and sediment-bound pollutants. For a Step 2 assessment it can be seen that the soluble pollutants pass the assessment. However, the site is accumulating (the low flow velocity of 0.03m/s is below the depositing threshold of 0.1m/s) and the deposition index is 141 (and is, therefore, greater than the threshold of 100). As a result, the sediment-bound pollutants fail the assessment. Following the logic chart (Figure A.3) and as prompted by HAWRAT, the next consideration for the sediments is to use Tier 2. To get the data required for Tier 2, a site visit was made to get the following data:

Bed width	3m
Manning’s n	0.07
Side slope	0.6m/m
Long slope	0.0004m/m

Following the Tier 2 assessment HAWRAT predicts the low flow velocity will be 0.08m/s and the deposition index will be 123, i.e. an accumulating site, with extensive deposition. Therefore, sediment-bound pollutants fail the assessment. HAWRAT advises that in order to avoid an exceedance of the deposition index, 19% of the sediment coming from the road will need to be settled out and removed prior to discharge.

Annual average concentrations of the soluble pollutants, at Step 2, are 0.1µg/l for dissolved copper and 0.44µg/l for dissolved zinc. These are below the EQS thresholds.

Table 5.2 shows that when the HAWRAT assessment fails and the comparison with EQSs passes, there are a number of actions which should be followed. The first is to factor in the effects of the proposed design and reassess.

Example A4

A dual two lane all-purpose road is being planned as a rural bypass. 9.1ha of the road drains to a small stream with a poor ecological status.The following data apply:

Data for Step 1 – Runoff quality:

AADT	25,000 vehicles/day
Climatic region	Warm-dry
Rainfall site	550mm

Data for Step 2 – River impacts:

95%ile river flow (Q_{95})	0.002 m^3/s
Base flow index	0.8
Impermeable road area drained	9.1ha
Permeable area draining to outfall	0ha (not available, use zero as precautionary)
Is the discharge in or within 1km upstream of a protected site for conservation?	No
Water hardness	35mg $CaCO_3$/l
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100 m downstream of the point of discharge?	No
Tier 1, Estimated river width	0.5 m

The Step 1 assessment determines that runoff quality exceeds the toxicity thresholds for both soluble and sedimentbound pollutants. For a Step 2 assessment it can be seen that the soluble pollutants fail the assessment. The site is also accumulating (low flow velocity of 0.05m/s) and deposition is extensive (deposition index of 563) resulting in sediment-bound pollutants failing the assessment. Following the logic chart (Figure A.3) and as prompted by HAWRAT, the next consideration for the sediments is to use Tier 2. To get the data required for Tier 2, a site visit was made to get the following data:

Bed width	0.3 m
Manning's n	0.07
Side slope	0.5m/m
Long slope	0.0002m/m

Following the Tier 2 assessment HAWRAT predicts the low flow velocity will be 0.04m/s and the deposition index will be 1602, i.e. an accumulating site with very extensive deposition. Therefore, sediment-bound pollutants fail the assessment. HAWRAT advises that in order to avoid an exceedance of the deposition index, 94% of the sediment coming from the road will need to be settled out and removed prior to discharge.

Annual average concentrations of the soluble pollutants, at Step 2, are 1.16μg/l for dissolved copper and 2.61μg/l for dissolved zinc. The copper concentration is above the EQS threshold for water in this hardness band and the outfall fails the assessment. Following the logic chart (Figure A.4), where the predicted annual average concentration exceeds the EQS, a Method B (detailed assessment) is required. However, if a proposed design exists which includes treatment, then this will likely reduce the annual average concentrations and may bring them below the EQSs. The relevant advice in Table 5.2 will depend on the outcome of the Method B and/or Step 3 assessment.

For this worked example, interrogation of HAWRAT at Step 3 reveals that 15% treatment would be required to reduce the annual average concentration and enable compliance with the EQSs, and 40% treatment would be required to pass the HAWRAT assessment for solubles. If a combination of dilution and treatment is used then, for example, a 30% reduction in both would be sufficient to pass.

The large percentage of settlement required to pass the HAWRAT assessment for sediment-bound pollutants reflects the relatively large road area that drains to a stream that, with low flow rates and low velocities, is not able to disperse the road derived sediment.

Example A5

A dual three lane motorway is being widened. 2.5 ha of the road drains to a large river with a high ecological status. The river has Special Area of Conservation (SAC) status, and is used for water supply (for both potable and agricultural use) and receives discharge from a sewage works. The motorway runs through the floodplain of the river. The following data apply:

Data for Step 1 – Runoff quality:

AADT	155,000 vehicles/day
Climatic region	Warm-dry
Rainfall site	600mm

Data for Step 2 – River impacts:

95%ile river flow (Q_{95})	2.94 m^3/s
Base flow index	0.5 (default value, actual value not available)
Impermeable road area drained	2.5ha
Permeable area draining to outfall	0ha (not available, use zero as precautionary)
Is the discharge in or within 1km upstream of a protected site for conservation?	Yes
Water hardness	322mg $CaCO_3$/l
Is there a downstream structure, lake, pond or canal that reduces the velocity within 100 m downstream of the point of discharge?	No
Tier 1, Estimated river width	6m

The Step 1 assessment determines that runoff quality exceeds the toxicity thresholds for both soluble and sediment bound pollutants. When the discharge is into (or within 1 km of) a protected site for conservation, HAWRAT halves the allowable number of exceedances per year of the toxicity thresholds (refer to Help Guide for further details). Despite this more stringent requirement, in this example, the soluble pollutants pass the Step 2 assessment.

The velocity of the river is 1.28 m/s (greater than the depositing threshold of 0.1m/s) and the river is judged to disperse sediments. However, the SAC designation of the receiving water produces an alert message on the user interface. This informs the assessor that further consideration needs to be given before the discharge is deemed acceptable. In the first instance this would involve a site visit to make a Tier 2 assessment.

Annual average concentrations of the soluble pollutants, at Step 2, are 0.00μg/l for dissolved copper and 0.01μg/l for dissolved zinc.

METHOD B – DETAILED ASSESSMENT

Worked Examples

Example B1

A Method A assessment of an outfall discharging from an existing motorway has predicted the annual average concentrations shown in Table C.1. The hardness of the receiving watercourse is 15mg/l $CaCO_3$.

Table C.1: Method B Worked Example 1

Soluble Pollutant	HAWRAT predicted annual average concentration (μg/l)	EQS* (μg/l)
Copper	3.91	1
Zinc	18.85	7.8

*corresponding to hardness and without bioavailability correction

As the predicted concentrations are above the EQSs, the bioavailability of the soluble pollutants should be checked using a simple assessment. To get the data to run the model, five water samples were taken from the watercourse just upstream of the outfall over a six month period. The average results from laboratory tests were:

pH 6.7

Water hardness (as Ca) 5.4mg/l

Dissolved Organic Carbon (DOC) 1.2mg/l

These data were fed into the simple assessment to determine the site-specific Probable Non-Effect Concentration (PNEC). The PNECs determined were:

Dissolved copper 2.7μg/l

Dissolved zinc 8.0μg/l

The annual average concentrations predicted by HAWRAT are greater than these PNECs indicating that there may be an impact. For copper (but not zinc), a more comprehensive bioavailability check is available that considers all the mitigating factors. In this example, with zinc failing the assessment, the practitioner may need to look to alternative design and/or mitigation and further consideration of the bioavailability of copper may be unnecessary. However, if there is need (or if zinc had passed the simple assessment) then copper should be checked using the more detailed assessment. To enable this, the water samples taken previously were also analysed for the following parameters:

Temperature 10.4 °C

Magnesium	4.2mg/l
Sodium	44mg/l
Potassium	1.1mg/l
Sulphate	6.6 mg/l
Chloride	56mg/l
Alkalinity	55ppm $CaCo_3$

These data were fed into the detailed copper assessment to determine the site-specific PNEC. The PNEC determined was:

Dissolved copper	3.8µg/l

The annual average concentration predicted by HAWRAT remains greater than the PNEC indicating that there may be an impact. Table 5.2 should be consulted as to how to proceed if the predicted annual averages fail against the EQSs.

Example B2

Example A2 from Method A concludes that the predicted annual average concentration of dissolved zinc (without mitigation) is in exceedance of the EQS, as shown in Table C.2. The hardness of the receiving watercourse is 70mg/l $CaCO_3$.

Table C.2: Method B Worked Example 2

Soluble Pollutant	HAWRAT predicted annual average concentration (µg/l)	EQS* (µg/l)
Copper	1.46	6
Zinc	8.02	7.8

*corresponding to hardness and without bioavailability correction

Method A also demonstrated a failure of the HAWRAT assessment for impacts of soluble pollutants in the shortterm. If treatment measures were proposed in order to mitigate against these predicted short-term impacts then they may also reduce the annual average concentrations to below the EQSs. Otherwise, an assessment of the bioavailability of the annual soluble pollutant concentrations will need to be made.

To get the data to run the simple assessment, five water samples were taken from the watercourse just upstream of the outfall over a six month period. The average results from laboratory tests were:

pH	7.2
Water hardness (as Ca)	32mg/l
DOC	3.7mg/l

These data were fed into the simple assessment to determine the site-specific PNEC. The PNECs determined were:

Dissolved copper	10.9µg/l
Dissolved zinc	13.9µg/l

The annual average concentrations predicted by HAWRAT are less than these PNECs and it can be concluded that the bioavailability is limited and that there is not likely to be a long-term impact (over the course of a year). The short-term failures of the solubles predicted by HAWRAT in Method A will still need to be resolved.

METHOD C – GROUNDWATER ASSESSMENT

Worked Examples

Example C1

A motorway is being constructed over a Regionally Important aquifer (Rf category). A cut of approximately 2 m deep is required and the invert level of the road drain will be 1.5 m below the cut depth. There are no public water supplies in the area.

Data required

Aquifer type:	Regionally Important aquifer (Rf category)
Site specific aquifer vulnerability:	Calculated in Step 1 below
Water level:	2.8mbgl (winter groundwater level)
Geology:	0-0.5 mbgl Made Ground 0.5-0.8 mbgl SILT 0.8-1.9 mbgl CLAY 1.9-2.5 mbgl GRAVEL 2.5-3.6 mbgl CLAY 3.6-5.4 mbgl SILT 5.4 mbgl LIMESTONE

Step 1: Calculate the site specific groundwater vulnerability

The site specific vulnerability should be calculated based on thickness and permeability of material between the invert level of the drain and the top of the aquifer.

The invert level of the drain will be 3.5 mbgl (2 m cut plus 1.5 m drain). This indicates that the geology below this level will be:

- 3.5-3.6 mbgl CLAY
- 3.6-5.4 mbgl SILT
- 5.4 mbgl LIMESTONE

There will be 1.9 m of Clay and Silt material between the invert level of the drain and the aquifer. Clay and Silt can be considered Moderate or Low permeability material. Based on this, and in line with the GSI groundwater vulnerability matrix, the site specific bedrock aquifer will have an '**Extreme**' vulnerability rating.

Step 2: Determine the appropriate response classification from the matrix

Based on an extreme vulnerability and an Rf aquifer, the response classification from the matrix will be **R2(2)**.

An R2(2) response indicates that a permeable drainage system can be used subject to a number of requirements. The requirements for R2(2), are those for R1, R2(1) and R2(2) and these are presented in table C.3.

Table C.3: Method C Worked Example 1

Relevant requirements from matrix	Site specific answers
1. There is a consistent minimum thickness of 1 m unsaturated subsoil, or 2 m in areas of karstified rock (Rk & Lk), beneath the invert level of the drainage system (Note 1).	The groundwater level is 2.8 mbgl and will be higher than the proposed 3.5 mbgl invert level of the drain. As such, the water table will be too high at this location to ensure the required unsaturated zone. This matrix requirement is not met.
2. During all stages of design particular attention must be paid to the presence of karst features and additional assessments undertaken if required. If karst features are identified response R2 (3) must be applied as a minimum.	No karst features identified.
3. During all stages of design particular attention must be paid to receptors (such as; public wells, group schemes, industrial water supply sources and springs) and additional assessments undertaken if required.	No additional receptors identified.
4. Where the subsoil is classed using BS5930 as; SAND, GRAVEL or SILT (in circumstances where the clay content is <10%) AND/OR is underlain by limestone bedrock, there is a consistent minimum thickness of 2 m unsaturated subsoil beneath the invert level of the drainage system. OR There is a minimum consistent unsaturated thickness 1 m of "appropriate material" (Note 3) beneath the invert level of the drainage system.	Silt is present, however PSD results indicate that the clay content is 12% so this requirement doesn't apply. As the site is underlain by limestone the R2(2) response requires a minimum 2 m unsaturated zone. The site conditions do not meet this criteria as such this matrix requirement is not met. As there is no unsaturated zone at the site the requirement for 1 m of 'appropriate material' (Note 3) is also not met.
5. Where a gravel aquifer is present, a consistent minimum thickness of 3 m unsaturated subsoil	No gravel identified.

beneath the invert level of the drainage system must be present	

Result

The water table at this location is too high to maintain an unsaturated zone of the required thickness beneath the invert level of the drain. This indicates that the site is not suitable for permeable drainage. However, mitigation measures can be incorporated into the design at this stage of the process. The assessment should be reapplied.

Example C2

A motorway is being constructed at grade over a Locally Important aquifer (Lm category). The invert level of the road drain will be 1.5 m below the road. The site is located within the Source Protection Area of a public supply well.

Data required

Source Protection Area:	Yes
Site specific aquifer vulnerability:	Calculated in Step 1 below
Water level:	3.5mbgl (winter groundwater level)
Geology:	0-0.1 mbgl Topsoil
	0.1-0.9 mbgl SILT
	0.9-1.3 mbgl GRAVEL
	1.3-3.6 mbgl SAND
	3.6-7.2 mbgl CLAY
	7.2 -12.1 mbgl SILT
	12.1 mbgl SANDSTONE

Step 1: Calculate the site specific groundwater vulnerability

The site specific vulnerability should be calculated based on thickness and permeability of material between the invert level of the drain and the top of the aquifer.

The invert level of drain will be 1.5 mbgl. This indicates that the geology below this level will be:

- 1.5-3.6 mbgl SAND
- 3.6-7.2 mbgl CLAY
- 7.2-12.1 mbgl SILT
- 12.1 mbgl SANDSTONE

There will be 10.6 m of Sand, Silt and Clay material between the invert level of the drain and the aquifer. Clay and Silt can be considered Moderate or Low permeability material while Sand has a high permeability. It is assumed an overall Moderate permeability would apply to the material. Based on this, and in line with the GSI groundwater vulnerability matrix, the site specific bedrock aquifer will have a 'Moderate' vulnerability rating.

Step 2: Determine the appropriate response classification from the matrix

Based on a moderate vulnerability and the location within a Source Protection Area, the response classification from the matrix will be **R3(1)**.

An R3(2) response indicates that a permeable drainage system are not generally acceptable unless a number of requirements are met. The requirements for R3(1), are those for R1, R2(1), R2(2), R2(3) and R3(1) and these are presented in table C.4.

Table C.4: Method C Worked Example 2

Relevant requirements from matrix	Site specific answers
1. There is a consistent minimum thickness of 1 m unsaturated subsoil, or 2 m in areas of karstified rock (Rk & Lk), beneath the invert level of the drainage system (Note 1).	The groundwater level is 3.5 mbgl and is 2 m below the invert level of the drain. This 2 m unsaturated zone meets the requirement of the response matrix.
2. During all stages of design particular attention must be paid to the presence of karst features and additional assessments undertaken if required. If karst features are identified response R2 (3) must be applied as a minimum.	No karst features identified.
3. During all stages of design particular attention must be paid to receptors (such as; public wells, group schemes, industrial water supply sources and springs) and additional assessments undertaken if required.	Public water supply identified and accounted for in this assessment.
4. Where the subsoil is classed using BS5930 as; SAND, GRAVEL or SILT (in circumstances where the clay content is <10%) AND/OR is underlain by limestone bedrock, there is a consistent minimum thickness of 2 m unsaturated subsoil beneath the invert level of the drainage system. OR There is a minimum consistent unsaturated thickness 1 m of "appropriate material" (Note 3) beneath the invert level of the drainage system.	Silt is present, however PSD results indicate that the clay content is 11% so the requirement of 2 m for this criteria does not apply. Limestone is not present so this specific requirement for 2 m unsaturated zone does not apply. Testing of the material confirms it meets the minimum classification of note 3 and as such a 1 m unsaturated zone is required. The site meets these criteria.
5. Where a gravel aquifer is present, a consistent minimum thickness of 3 m unsaturated subsoil beneath the invert level of the drainage system must be present	Not relevant.
6. The drainage system shall be at least 15m away from karst features that indicate enhanced zones of high bedrock permeability (e.g. swallow holes and dolines (collapse features)).	Not relevant.

Relevant requirements from matrix	**Site specific answers**
7. The site investigation shall pay particular attention to the possibility of instability in these karst areas.	Not relevant.
8. Discharge to surface water is not possible. If this is the case, then additional assessments by an appropriately qualified groundwater specialist are required to determine the risk to groundwater resources (the aquifer).	Discharge to surface water is not possible. A hydrogeologist undertook a risk assessment to determine the risk to the aquifer and determined there would be none.

Result

A permeable drainage system can be used in this location.

Example C3

A motorway is being constructed at grade over a Locally Important gravel aquifer (Lg category). The invert level of the road drain will be 1.5 m below the road. There are no public water supplies in the area.

Data required

Aquifer type:	Locally Important gravel aquifer (Lm category)
Site specific aquifer vulnerability:	Calculated in Step 1 below
Water level:	4.6mbgl (winter groundwater level)
Geology:	0-0.2 mbgl Topsoil 0.2-0.5 mbgl SILT 0.5-1.3 mbgl SAND 1.3-1.5 mbgl CLAY 1.5-2.3 mbgl GRAVEL 2.3-5.4 mbgl SILT 5.4-6.8 mbgl SAND 6.8-18.2 mbgl GRAVEL 18.2 mbgl LIMESTONE

Step 1: Calculate the site specific groundwater vulnerability

The site specific vulnerability should be calculated based on thickness and permeability of material between the invert level of the drain and the top of the aquifer. The aquifer is determined to be the gravel bed extending from 6.8-18.2 mbgl

The invert level of drain will be 1.5 mbgl. This indicates that the geology between the invert level of the drain and the gravel aquifer:

- 1.5-2.3 mbgl GRAVEL

- 2.3-5.4 mbgl SILT
- 5.4-6.8 mbgl SAND
- 6.8-18.2 mbgl GRAVEL

There will be 5.3 m of Sand, Gravel, Clay and Silt material between the invert level of the drain and the aquifer. Clay and Silt can be considered Moderate or Low permeability material while sand and gravel can be considered high permeability material. Based on this, and in line with the GSI groundwater vulnerability matrix, the site specific bedrock aquifer will have an '**High**' vulnerability rating.

Step 2: Determine the appropriate response classification from the matrix

Based on an extreme vulnerability and an Lg aquifer, the response classification from the matrix will be **R2(2)**.

An R2(2) response indicates that a permeable drainage system can be used subject to a number of requirements. The requirements for R2(2), are those for R1, R2(1) and R2(2) and these are presented in table C.5.

Table C.5: Method C Worked Example 3

Relevant requirements from matrix	Site specific answers
1. There is a consistent minimum thickness of 1 m unsaturated subsoil, or 2 m in areas of karstified rock (Rk & Lk), beneath the invert level of the drainage system (Note 1).	The groundwater level is 4.6 mbgl indicating it will be 3.1 m below the invert level of the drain so the unsaturated zone will be 3.1 m thick, which meets the reponse criteria.
2. During all stages of design particular attention must be paid to the presence of karst features and additional assessments undertaken if required. If karst features are identified response R2 (3) must be applied as a minimum.	No karst features identified.
3. During all stages of design particular attention must be paid to receptors (such as; public wells, group schemes, industrial water supply sources and springs) and additional assessments undertaken if required.	No additional receptors identified.
4. Where the subsoil is classed using BS5930 as; SAND, GRAVEL or SILT (in circumstances where the clay content is <10%) AND/OR is underlain by limestone bedrock, there is a consistent minimum thickness of 2 m unsaturated subsoil beneath the invert level of the drainage system. OR 5. There is a minimum consistent unsaturated thickness 1 m of "appropriate material" (Note 3) beneath the invert level of the drainage system.	Sand, gravel and silt are present and the material is underlain by limestone bedrock. An unsaturated zone of 2 m is required and is met by the site.
6. Where a gravel aquifer is present, a consistent minimum thickness of 3 m unsaturated subsoil beneath the invert level of the drainage system must be present	An unsaturated zone of 3 m is required and this criteria is met.

Result

The site is suitable for permeable drainage.

Summary

The Designer should present worked examples of the calculations, following the methodology and presenation outlined above. They should also present a summary table of the results in the format shown in Table C.6.

Table C.6: Summary table of GPR assessment

Chainage / Soakaway ID	Calculated vulnerability	Aquifer type OR Source Protection Area	Matrix Response category	Suitable for use of a permeable drainage system?

METHOD D – SPILLAGE RISK ASSESSMENT

Worked Examples

Example D1

An urban motorway is being widened from dual 2 to dual 3 lanes, including hard shoulders. A 2 km length of the road drains to a reach of a small river of moderate ecological status. There is a junction within this length. The response time for emergency is less than 20 minutes. The following data apply:

Water body type	Surface watercourse
Road length (RL)	2km
AADT for two-way flow	100,000 vehicles/day
HGV %	15
Length of slip roads	0.8km
AADT for slip roads	8,000 vehicles/day

From Table A.5 Spillage rates, SS:

For main carriageway	0.36
For slip road	0.43

The probability of a spillage, PSPL, is given by:

PSPL = RL x SS x (AADT x 365 x 10^{-9}) x (%HGV/100)

See Figure C.3, which shows lengths of road having different spillage probability rates:

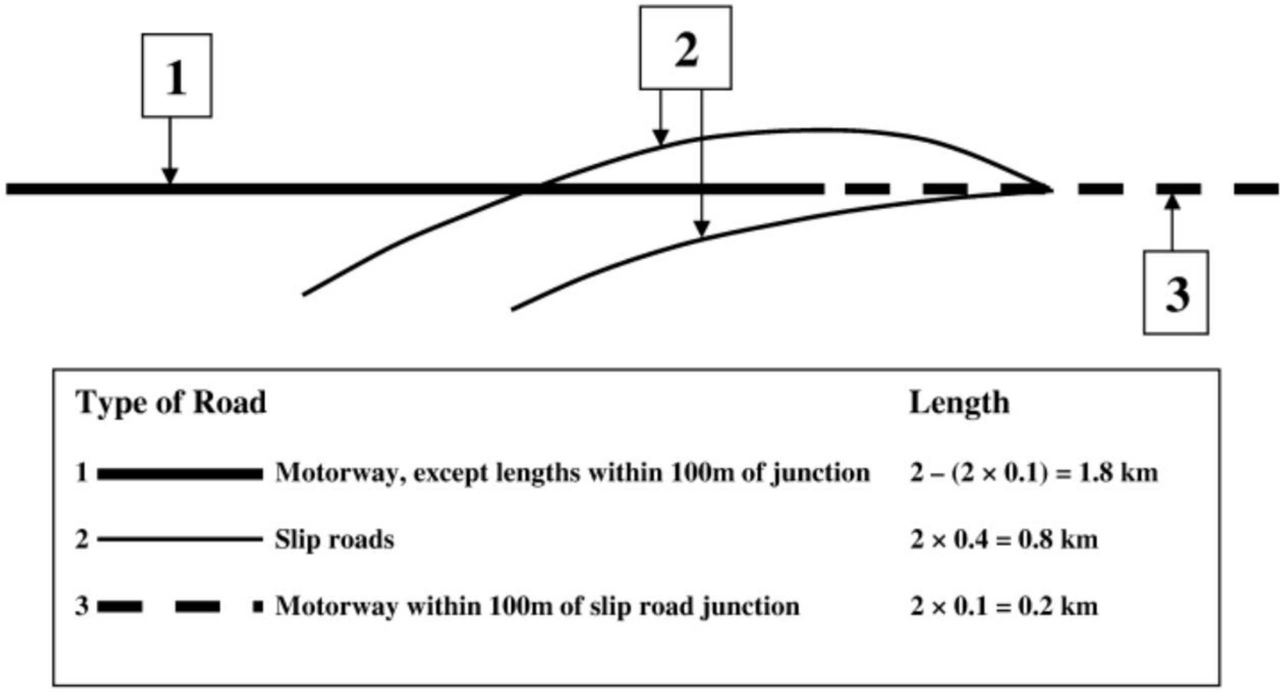


Figure C.3: Road Lengths with Different Spillage Probability Rates for Example D1

1 For the length of main road excluding 100 m either side of junction

P_{SPL} = (2 - 0.2) x 0.36 x (100,000 x 365 x 10^{-9}) x (15/100)

= 3.55 x 10^{-3}

2 For the length of main road within 100 m of the slip road junction:

P_{SPL} = 0.2 x 0.43 x (100,000 x 365 x 10^{-9}) x (15/100)

= 4.71 x 10^{-4}

3 For the slip roads:

P_{SPL} = 0.8 x 0.43 x (8,000 x 365 x 10^{-9}) x (15/100)

= 1.51 x 10^{-4}

Total annual probability of a spillage:

P_{SPL} = (3.55 + 0.47 + 0.15) x 10^{-3}

= 4.17 x 10^{-3}

From Table A.6, probability of a serious pollution incident arising as a result of a spillage:

P_{POL} = 0.45

Annual probability of a serious pollution incident is given by:

P_{INC} = P_{SPL} x P_{POL}

= $4.17 \times 10^{-3} \times 0.45$

= 1.9×10^{-3}

= 0.19%

This is less than 1%, so no further spillage prevention measures will be required to reduce the risk of a serious pollution incident.

Example D2

A dual 2 lane all-purpose road is being planned as a rural bypass in a remote area. 12 km of the road drains to a high quality river which is used for irrigation. Two roundabouts on the main road are located within this length, and there is a grade separated junction leading to a roundabout located above the main road. The following data apply:

Water body type	Surface watercourse
Road length	12km
AADT for trunk road	40,000 vehicles/day
Slip roads	2km
AADT for slip roads	6,000 vehicles/day
HGV % on all roads	20

From Table A.5 Spillage rates, SS:

For main carriageway	0.29
For roundabouts	3.09
For slip roads	0.83

The probability of a spillage, PSPL, is given by:

PSPL = RL x SS x (AADT x 365 x 10^{-9}) x (%HGV/100)

See Figure C.4, which shows lengths of road having different rates:

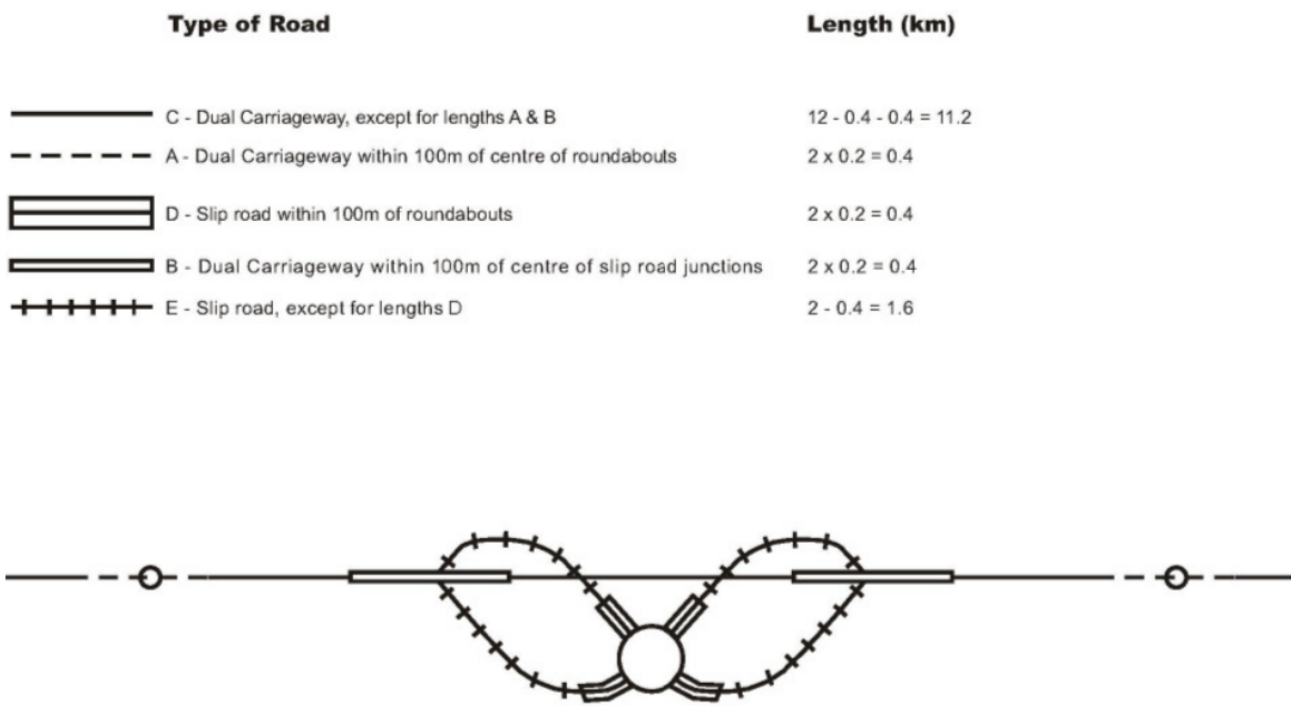


Figure C.4: Road Lengths with Different Spillage Probability Rates for Example D2

1 For the length of road excluding the 100 m either side of the two roundabouts and the slip road junctions

P_{SPL} = $(12 - 0.4 - 0.4) \times 0.29 \times (40{,}000 \times 365 \times 10^{-9}) \times (20/100)$

= 9.48×10^{-3}

2 For the length of road within 100 m of the trunk road roundabouts:

P_{SPL} = $0.4 \times 3.09 \times (40{,}000 \times 365 \times 10^{-9}) \times (20/100)$

= 3.61×10^{-3}

3 For the length of road within 100 m of the slip roads:

P_{SPL} = $0.4 \times 0.83 \times (40{,}000 \times 365 \times 10^{-9}) \times (20/100)$

= 9.7×10^{-4}

4 For the slip roads excluding the 100 m either side of the local road roundabouts

P_{SPL} = $(2 – 0.4) \times 0.83 \times (6{,}000 \times 365 \times 10^{-9}) \times (20/100)$

= 5.8×10^{-4}

5 For the length of slip roads within 100 m of the local road roundabouts:

P_{SPL} = $0.4 \times 3.09 \times (6{,}000 \times 365 \times 10^{-9}) \times (20/100)$

= 5.4×10^{-4}

Total annual probability of a spillage:

P_{SPL} = $(9.48 + 3.61 + 0.97 + 0.58 + 0.54) \times 10^{-3}$

= 1.519×10^{-2}

From Table A.6, the probability of a serious pollution incident arising as a result of a spillage:

P_{POL} = 0.75

Annual probability a serious pollution incident is given by:

P_{INC} = $P_{SPL} \times P_{POL}$

= $1.519 \times 10^{-2} \times 0.75$

= 1.14×10^{-2}

= 1.14%

This is greater than 1%, so spillage prevention measures will be required to reduce the risk of a serious pollution incident.

Reporting of Significance of Potential Effects – Worked Example

NRA's Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes should be used when reporting the potential effects of a road project. Table B.1 should be completed and submitted as part of the report. An example of a completed Table B.1 is given below.

Table C.7 – Worked Examples for Reporting of Significance of Potential Effects

Potential impact	feature	attribute	quality	importanc	mitigation	magnitude[1]	significance[1]
Flooding	River A	Conveyance of flow	High	Very high	–	Negligible	Neutral
Water quality	River B	Biodiversity	Moderate	Medium	The use of vegetated drainage systems, attenuation ponds	Minor adverse[2]	Slight
Water quality	River C	Biodiversity	Poor	Low	Filter drain, grass lined channel, detention pond	Minor adverse[3]	Neutral
Water quality	Regionally Important Aquifer	Water supply	High	High	–	Moderate adverse[4]	Large[4]
Water quality	Locally Important Aquifer	Water supply	High	Medium	–	Moderate adverse[4]	Moderate[4]
Water quality	River D	Biodiversity	Moderate	Medium	–	Negligible	Neutral
Water quality	River E	Biodiversity	High	Very High	–	Moderate adverse[4]	Large/ Very Large[4]
Water quality	River E	Water supply	High	Medium	–	Moderate adverse[4]	Moderate/ Large[4]
Floodplain loss	River F	Floodwater storage	Good	Medium	–	Moderate adverse[5]	Moderate/ Large[5]
Flooding from increased surface water runoff	River F	Conveyance of flow	Good	Medium	The use of SuDS drainage system.	Negligible	Neutral

Notes to Table C.7

1 Estimate the difference in cost between providing the maximum feasible flow width (total width of floodplain) and the minimum feasible Magnitude and Significance should be post-mitigation.
2 Solubles still fail HAWRAT assessment despite mitigation measures applied at Step 3.
3 Sediments still fail HAWRAT assessment despite settlement measures proposed at Step 3.
4 Mitigation measures not yet proposed.
5 No compensation for loss of floodplain yet proposed.

APPENDIX D: FIELD LOG SHEET

Routine Runoff Assessment – Field Logging Sheet	
Date	
Road Name	
Outfall Number	
Watercourse	
Grid Reference	
Field Staff & Organisation	

Road and Drainage System Description, e.g. number of lanes, road gradient, surfacing material, existing pollution control devices (filter drains, oil interceptors, swales, penstocks, balancing ponds etc.), outfall layout.

Long slope of watercourse downstream of outfall (measure three times and take average)			
Level near outfall (m) (to nearest 5 mm or better)	Level downstream (m) (to nearest 5 mm or better)	Distance between points along stream (m)	Gradient (m/m)
1.	1.	1.	1.
2.	2.	2.	2.
3.	3.	3.	3.
		Average:	

Bed width (m)	
Flow width (m)	
Bank full width (m)	
Flow depth (take average across stream) (m)	
Bank full depth (m)	
Manning’s n value	

Bed composition:	Cobbles %	Gravel %	Sand %	Silt & Finer %

Water Quality Location of water sample(s) and qualitative observations of water quality (clear/cloudy/murky, colour, any odour). Other quantitative measurements if made (e.g. temperature, conductivity, pH, redox, dissolved oxygen etc.).

Water Sample ID (if taken)	

Qualitative assessment of flow velocity e.g. stagnant, slow, medium, fast (laminar), fast (turbulent)
Is stream bed dry? Is stream likely to dry up in summer?
Is there a protected site for conservation within 1 km downstream? If yes, specify.
Is there a downstream structure, lake, pond or canal which reduces stream velocity within 100 m of the outfall?
Presence/absence of confluences (upstream or downstream of outfall, relative size).
Evidence of recent flooding?
Description of watercourse e.g. straight/meandering, braided channel, river cliffs, substrate type, vegetation, approximate depth, bed composition, river fauna seen.
Other observations Weather and recent rainfall. Is the outfall discharging (if yes, describe appearance of water)? Surrounding land use. Presence of non-road outfalls (and source of discharge, e.g. sewage works, factory, agricultural runoff). Soil/rock type. Presence of soakaways.

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