WFD Pressures and Impacts Assessment Methodology

GUIDANCE ON PRESSURES AND IMPACTS METHODOLOGY

Paper by the Working Group on Groundwater and Working Group on Characterisation and Reporting

Guidance document no. GW4

<table>
<tr><td colspan="5">This is a guidance paper on the application of a Pressures and Impacts Methodology. It documents the principles to be adopted by River Basin Districts and authorities responsible for implementing the Water Framework Directive in Ireland.</td></tr>
<tr><th colspan="5">REVISION CONTROL TABLE</th></tr>
<tr><th>Status</th><th>Approved by National Technical Co-ordination Group</th><th>WFD Requirement</th><th>Relevant EU Reporting Sheets</th><th>Date</th></tr>
<tr><td>Final</td><td>August 2003</td><td>Pressures and Impacts</td><td>SWPI 1, 2, 3, 4, 5, 6, 7, 8 & 9
GWPI 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11</td><td>8 August 2003</td></tr>
</table>

Contents

Figures

Tables

Water Framework Directive
Pressures and Impacts Assessment Methodology

Summary and General Principles

- This Methodology is influenced by and follows the principles outlined in a UKTAG Drafting Group paper.

- It proposes a framework that should be applied to **all** water bodies. This is summarised in Figure 1.

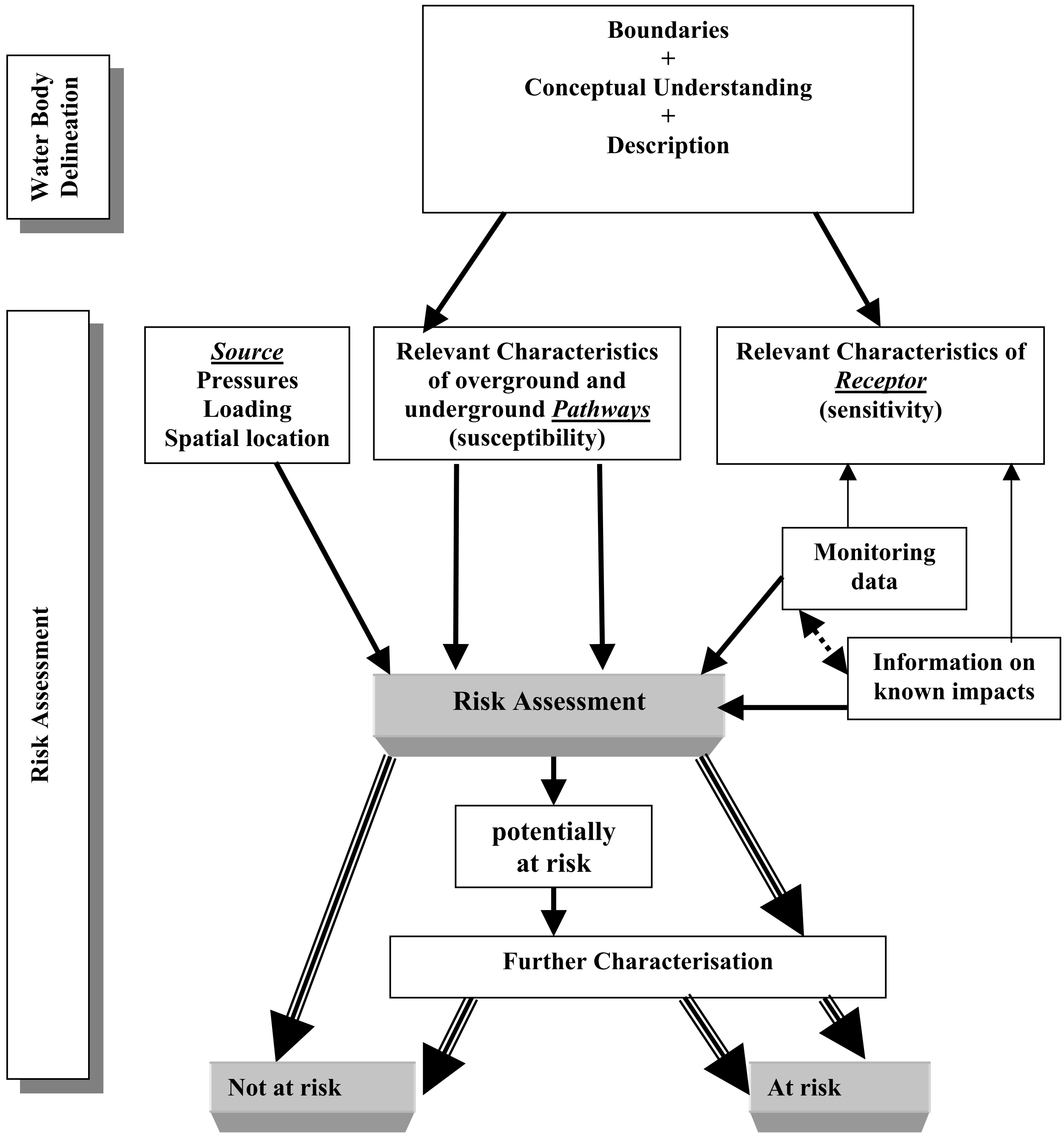


Figure 1 Summary of risk assessment approach

- The conventional '**source-pathway-receptor**' model is used as the framework for applying the risk concept.

- The Methodology is largely a screening process, using matrices and layers in a GIS which are based on available data.

- Monitoring data exist to varying degrees of adequacy. In this report, monitoring and monitoring data are placed in a broad risk assessment context, which requires analysis and understanding of the relationships and linkages between pressures, environmental pathways and impacts. Where the data are adequate, they are a critical component of the Methodology; firstly, they are the major factor in determining the risk category of the water body; and secondly, they can provide threshold values to validate pressure and impact assessments.

- The stages in the process are summarised in Table 1.

Table 1 Summary of main stages in pressure and impact assessment

Step[1]	Description
1	Delineate and undertake evaluation and description of water bodies
2	Develop a 'conceptual understanding/model' of the river basin as a 3-dimensional entity, where emphasis is placed on the interconnection and interdependencies between the various components of the water cycle.
3	Identify and delineate water bodies to be assessed (surface water, lakes, transitional, coastal and groundwater). **These water bodies may subsequently be sub-divided on completion of the pressure and impact analysis.**
4	Review existing monitoring data to determine whether there are appropriate indicators to determine whether the water body is 'at risk' or not. Draw conclusions on the value and relevance of the data, and highlight gaps.
5	Obtain and incorporate relevant GIS layers on the physical characteristics of the RBD (e.g. soil, aquifers, etc.)
6	Develop 'susceptibility' matrices for each water body type for the main types of pollutants
7	Map and evaluate known impacts, e.g. on hydromorphology.
8	Obtain relevant available information on pressures and activities that are likely to pose a risk to the status of a water body. Install info. in RBD GIS.
9	**Group all pollutants into 'pollutant types'.** **Develop general threshold values for particular pressure magnitudes and 'pollutant types', in the form of matrices.**
10	Evaluate and report on 'sensitivity' of receptors, particularly ecosystems.
11	Develop threshold values for chemical and ecological parameters that indicate the 'risk' categories.
12	Combine relevant pressures, susceptibility and sensitivity in the form of matrices for both water bodies and ecosystems.
13	Apply matrices to RBD GIS.
14	Use available monitoring data to refine the threshold values and the 'risk' conclusions. If necessary, re-evaluate and amend matrices developed under previous steps.
15	For each water body, conclude whether 'at risk', 'not at risk' or 'potentially at risk'.
16	Undertake 'further characterisation' on bodies 'at risk' and 'potentially at risk'.

[1] Some of these steps will be undertaken simultaneously and can be in a different order.

Water Framework Directive
Pressures and Impacts Assessment Methodology

1. Introduction

1.1 Background

This report is based on the principles and ideas in draft UKTAG papers. The report was drafted initially by Donal Daly and Garrett Kilroy. The approach was agreed at a meeting of the Working Group on Characterisation and Reporting on 6/6/2003. The members of the GW WG are listed in Section 9. It was decided at the meeting that the report should be developed by a Working Group sub-committee or Drafting Group, which would meet in the GSI on 14th July, prior to reporting to the WFD Co-ordination Group on 17th July.

The nominated Drafting Group members are:

Mr Donal Daly, Geological Survey of Ireland
Ms Grace Glasgow, SERBD (KMM)
Dr Garrett Kilroy, Shannon Pilot River Basin
Mr Martin McGarrigle, Environmental Protection Agency
Dr Jim Bowman, Environmental Protection Agency
Mr Francis O'Beirn, Marine Institute
Mr Thomas Quinlivan, Department of Agriculture and Food
Mr Paul Mills, Compass Informatics

The report was considered at the Groundwater Working Group meeting on 10th June. The amendments recommended at that meeting are included here. Subsequent to the meeting of the Working Group on Characterisation and Reporting on 6/6/2003, Grace Glasgow and Garrett Kilroy agreed to develop the methodology further. This process involved meeting with each of the other water quality experts in advance of the meeting at GSI on 14th July. Meetings were held with Jim Bowman on 3rd July, Francis O'Beirne on the 4th of July and Martin McGarrigle on the 10th July. Output from these meetings is presented in Section 3 of this document. In summary, these meetings provided the first screening for relevant pressures for each of the water categories. Also provided in this document in Appendix A are risk assessment criteria for the most highly relevant pressures.

The risk methodology was presented to the drafting group on 14th July and action points for further development of the document agreed. These action points are largely incorporated into this revision.

The main outstanding tasks for further development of this document were (they have now been addressed):

1. **The detailed review of the Risk Criteria Tables by relevant experts**
2. **The grouping of pollutants into 'pollutant types'**
3. **Categorising the magnitude of pressures**
4. **Development of thresholds for particular pressures and 'pollutant types' in the form of matrices.**

1.2 Record of Submissions

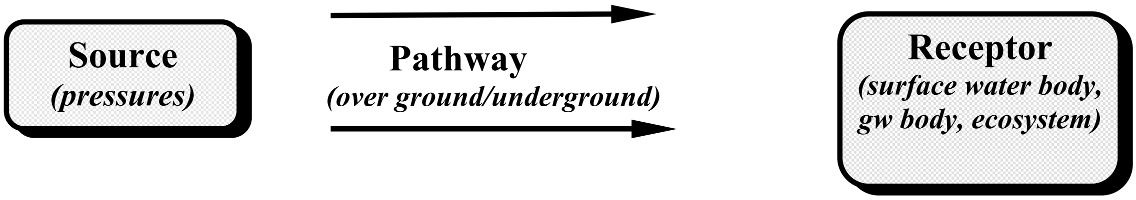
Several submissions have been given to drafting group members on previous drafts of this document. In order to keep track of the development of this document it was agreed at the July 14th meeting of the drafting group to insert a section detailing submissions on this document. The table below lists the status of these submissions and the extent to which recommendations are planned for inclusion by the drafting group.

Submitted By	Date	Format	Content	Actions by drafting group
Jim Bowman	5-6-03 16-7-03	Word Doc Word Doc	Suggested criteria for lakes Criteria for lakes to be used for the intercalibration exercise	Superseded by 16-7-03 document Incorporated into Chap. 7
Conor Cleneghan	17-6-03	email	1. Forecasting changes to 2015 2. Addressing cumulative effects 3. Amalgamating water bodies & use of analogous water bodies 4. Assessment of uncertainty	1. For later draft 2. For later draft 3. For later draft 4. For later draft
Martin McGarrigle	12-6-03	email	1. High quality sites should be defacto at risk 2. Use all available long-term data 3. First order streams should not be neglected in the process 4. ERTDI agricultural eutrophication project (LS2) should be used	1. Yes – receptor could be weighted to reflect status 2. Yes 3. Wait for GIS stage 4. Will be considered when available
Thomas Quinlivan	1-7-03	email	Pressure thresholds for agriculture, e.g. use of kg organic N / ha	Wait for threshold development stage
Donal Daly	8-8-03	email	How do we take account for relative areas of a water body with differing degrees of pressures and pathway susceptibility?	Thresholds will be required: e.g. areas with >10% conifer may be at risk

2. Overall Approach

The main objective of pressures and impacts assessment is to decide whether water bodies are 'at risk' of failing to meet the Directive's environmental objectives.

A formal 'risk assessment' approach is used. The risk concept in essence is basic and simple:



The risk depends on all three elements. For example:

- If there are no pressures, there is no risk to receptors, even if they are 'susceptible' and/or 'sensitive'.
- If there is a significant thickness of low permeability subsoil (i.e. the vulnerability is low), even if there are significant pressures, the 'susceptibility' of groundwater is low and therefore the risk to groundwater is low.
- If the receptor is particularly resilient (i.e. is not sensitive), such as calcareous lakes with a buffering capacity to acidification, then the risk is diminished.

The risk assessment approach is combined with the 'Drivers-Pressures-State-Impact-Response' model shown in Figure 1.

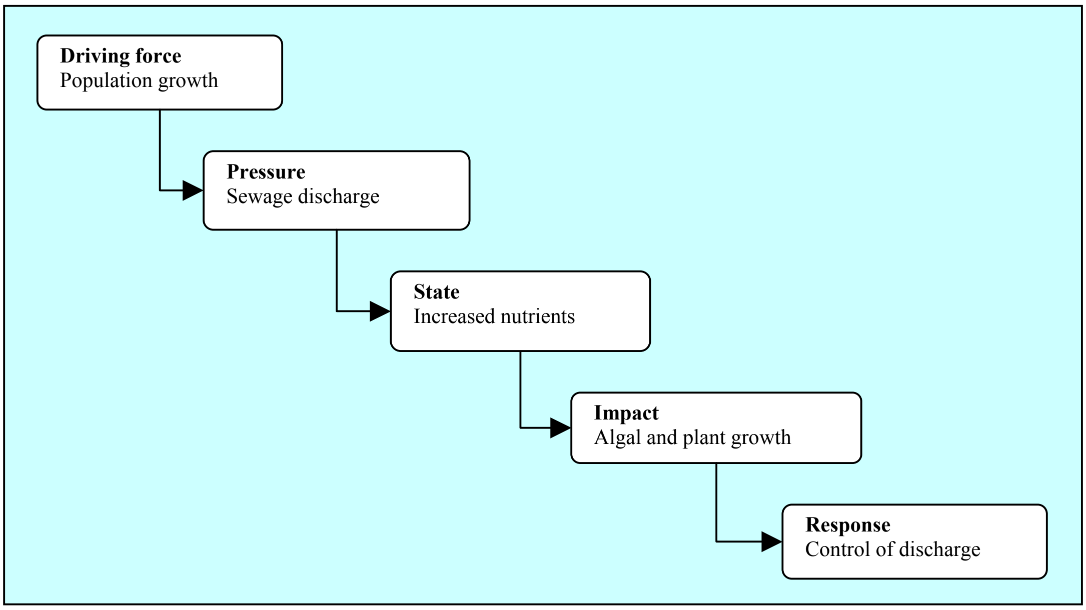


Figure 1 An illustration of the DPSIR analytical framework (copied from IMPRESS Guidance)

The proposed overall approach for pressure and impact assessment is outlined in Figure 2. It is recommended that the same approach should be applied to **all** "water categories" (i.e. groundwater, rivers, lakes, transitional & coastal) in order to maintain consistency and linkages. This is in line with the IMPRESS guidance, which emphasises having a good 'conceptual understanding' of the various relevant aspects of water (flow, chemistry, ecology), and advocates 'integration' as a key concept underlying the WFD.

Matrices are used to assist in the assessment of whether a water body is at risk. Methods such as exceedances of numerical threshold values are amenable to representation by a matrix.

As the initial assessment of pressures and impacts needs to be completed by the end of 2004, it should be mainly a screening exercise, using layers in the RBD GIS. The proposals outlined in this report are based on this assumption.

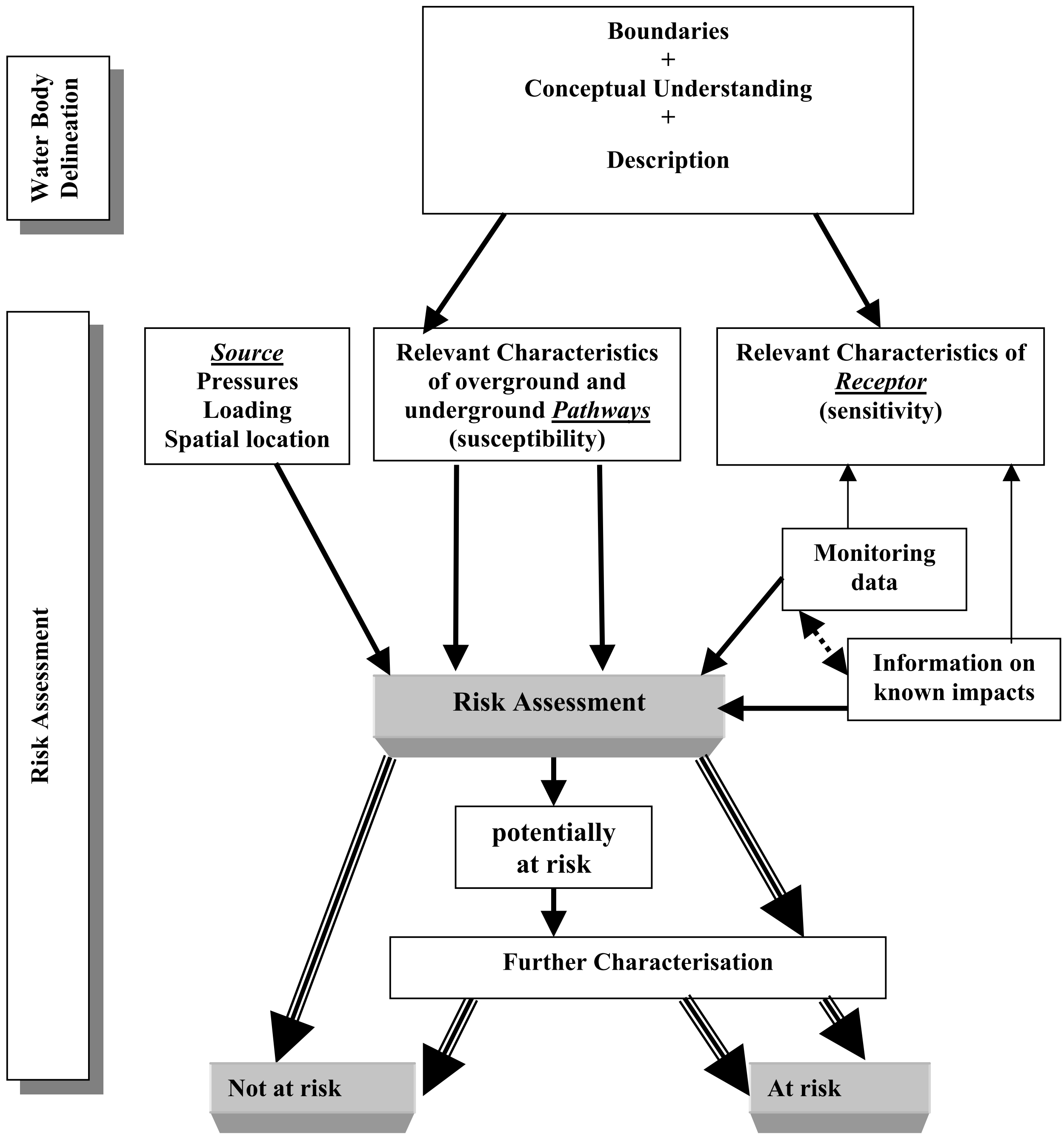


Figure 2 Summary of risk assessment approach

3. Screening and Mapping for Pressures

3.1 Introduction

Screening for pressures involves identifying, collating and mapping activities or potential pressures in the RBD GIS. Useful qualifiers in considering pressures are as follows:

1. Spatial nature
   - Point
   - Diffuse

2. Temporal nature
   - Continuous
   - Episodic
   - Periodic

3. Control
   - Regulated at source
   - Not regulated at source

As a first step in the screening process meetings were held with water category experts Jim Bowman (lakes), Francis O'Beirn (coastal/transitional) and Martin McGarrigle (rivers) as outlined in the introduction. The purpose of these meetings was to identify high relevance pressures for each of the water categories. The process carried out is summarised in the schematic in Figure 3. The first step was to go back to the Directive itself and identify the main pressures required for assessment. This 'incomplete' pressure list was derived from the IMPRESS guidance document (Table 4.1).

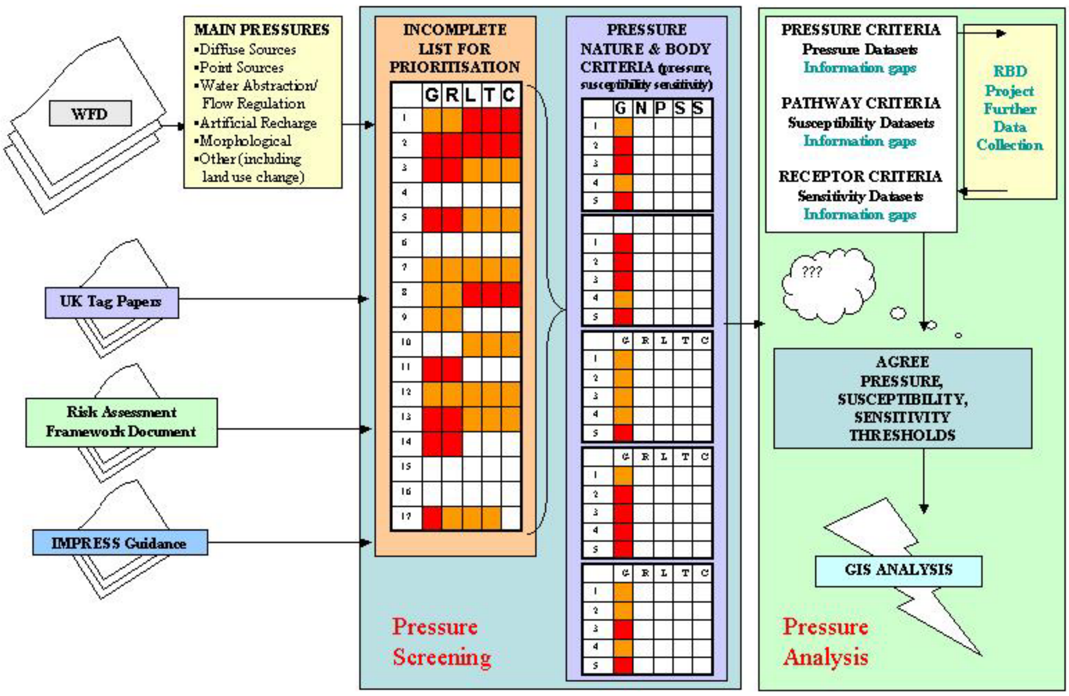


Figure 3 Screening process to identify high relevance pressures and risk criteria

Pressures which were identified with a relevance score of 4 or 5, were then examined by Grace Glasgow and Garrett Kilroy to identify the type and magnitude of the pressure and criteria for the pathway and receptor. Output from this assessment is presented in Appendix A. **These tables were reviewed by the Characterisation and Reporting Working Group.**

3.2 Pressure datasets identified as necessary for screening process

During this screening process, the following datasets / information were identified as necessary to populate the RBD GIS in order to address all priority pressures.

Required dataset which are available	**Required datasets which are unlikely to be available Use of surrogates may be required**
Land use Land use change Livestock Density Chemical fertilizer loadings Soil P levels Enterprise distribution (e.g. arable %age) WWTP PE & level of treatment Water treatment plant volume Industrial site chemical usage Mining practices Peat extraction practices Aquaculture enterprise size Abstraction total volume Exotic species presence Boat maintenance area Sheep dip practices (REPS uptake) FIPS & Coillte databases Rainfall intensity	Pesticide usage? Plant protection product usage? Slurry storage facility deficits? Manure depot size? Cattle mart turnover? Silage production practices? Storm water overflow volume of spillage? Septic tank population served? Landfill & dump leachate composition? Extent of physical works (dredging, engineering, trawling, Channel works etc)? Extent of recreational activities? Shipping activities? Forestry practices – felled, fertilized, drained areas? Sewage sludge spreadland inventories?

3.3 Next Steps

1. The relevant pollutants need to be grouped into 'pollutant types' based on similarities of mobility and toxicity. This will reduce the number of required risk matrices and simplify the RBD GIS.

2. The pressures that produce these pollutant types need to be categorised into pressure magnitudes. For some pressures this may take the form of percentages of a particular land cover type. For example, acidification pressure may be categorised into percentages of conifer plantation cover, i.e. High (>10%), Moderate (<10%), Low (0%) as set out in Table 15 of Chapter 6. In other cases, application ranges (e.g. kg N / ha) may be more appropriate.

3. Appropriate threshold levels need to be developed for identified pressures to determine whether the magnitude of these pressure put a given water body at risk. Some Irish examples are given in Section 8. The UK TAG documents provide many examples, as does material produced by EA regarding coastal/transitional waters. **The appropriateness of these thresholds was assessed by the Characterisation and Reporting Working Group and other expert groups.** The identified criteria and associated thresholds may then be integrated into the RBD GIS for risk analysis.

Table 1 Screening for relevant pressures for water bodies in each water category

PRESSURE CATEGORY	SECTOR	SECTOR ACTIVITY	Ground water	River	Lake	Trans'l	Coastal
DIFFUSE SOURCE	urban drainage (including runoff)	industrial/commercial estates	2	4	1	4	2
		urban areas (including sewer networks)	2	5	2	4	2
		Airports	4	4	4	N/A	N/A
		Roads	2	2	1	2	1
		railway tracks and facilities	1	1?	1	N/A	N/A
		Harbours	N/A	N/A	1	4	2-3
	agriculture diffuse	Arable, improved grassland mixed farming	3-4	2-4	4	4	3
		crops with intensive nutrient or <u>pesticide</u> usage or long bare soil periods (e.g. corn, potato, sugar beets, vine, hops, fruits, vegetables)	4	4	4	4	
		over grazing – leading to erosion	1	4	4	4	4
		horticulture, including greenhouses	1	4	4	4	2
		application of agricultural waste to land	3-4	5	5	4	4-5
	forestry	coniferous plantations	2	4	4	2	1
		planting/ground preparation	2	5	4	2	1
		Felling	2	4	3	2	1
		pesticide & herbicide applications	3-4	3		2	1
		fertilizer applications	3	1-4	1 – 4	2	1
		Drainage	2	4	3	2	1
		oil pollution	1	1	1	N/A	N/A
	other diffuse	sewage sludge recycling to land	2-4	5	1 – 3	3	2
		atmospheric deposition	N/A	1-4	1 – 4	1	1
		dredge spoil disposal into surface waters	N/A	N/A	1	4	4-5
		shipping/navigation	N/A	N/A	N/A	4	4
POINT SOURCE	waste water	municipal waste water primarily domestic	1	5	5	5	4
		municipal waste water with a major industrial component	1	5	5	5	4
		storm water and emergency overflows	1	5	5	4	4
		private waste water primarily domestic (septic tanks)	3-4	4	4	4	4-5
		private waste water with a major industrial component (IPC?)	3	5		2	?
		Harbours	N/A	N/A	2 – 3	2?	1
		*Water supply					
	industry (includes effluent & storage)	gas/petrol	4-5	3	3	2	1
		Chemicals, incl. Pharmaceutical industries (organic and inorganic)	4-5	3	3	4-5	2
		pulp, paper & boards	4	4	3	1	1
		woollens/textiles	3	5	3	1?	1
		iron and steel (includes galvanising)	3	2	3	1?	1
		food processing (incl. Agric industries)	4	4	3	3-4	1
		brewing/distilling	3	4	3	?	1
		electronics and other chlorinated solvent users	4	3	3 – 4	4-5	4
		wood yards/timber treatment	4	4	3 – 4	4	4
		Construction	3	3	3	3	2
		power generation	1	3	2	3	2
		leather tanning (incl. Fell Mongering)	3	2	N/A	?	?
		Shipyards	N/A	N/A	N/A	4-5	3
		boat builders	N/A	N/A	2	N/A	2
		other manufacturing processes	3	3	3	3	2
	Mining	active deep mine	5	3	N/A	1	1
		active open cast coal site/quarry	3-4	4		1	1
		gas and oil exploration and production	3-4	4	N/A	1	3
		peat extraction	2	4	3	1	1

Table 1 (cont'd) Screening for relevant pressures for water bodies in each water category

PRESSURE CATEGORY	SECTOR	SECTOR ACTIVITY	Ground water	River	Lake	Trans'l	Coastal
POINT SOURCE (cont'd)		abandoned coal (and other) mines, spoil heaps (bings),tailings dams	5		3	1-4	1
	contaminated land	old landfill sites	5	5	5	4	4
		urban industrial site (organic and inorganic)	5	4	N/A	?	?
		rural sites (includes illegal dumps)	5	4	5	2	2
		military sites	1	1	1	1	1
	agriculture point	Slurry	5	5	5	2	4
		silage and other feeds	4	4	5	2	4
		sheep dip use	4	3	5	2	4
		manure depots	4	4	3	2	4
		farm chemicals	4	4	5	2	4
		agricultural fuel oils	3	3	1	2	2
	waste management	operating landfill site	4	4	3	2	2
		operating waste transfer stations, scrap yards etc.	4	3	3	3	2
	aquaculture	inland fish farming / watercress / aquaculture	N/A	5	3 – 4	1	4
		shellfish	N/A			3	4
		marine cage fish farming	N/A	N/A	N/A	2	4
ABSTRACT-ION	reduction in flow	abstractions for agriculture, potable supply, industry, fish farms, hydro-energy, quarries/open cast coal sites, navigation (e.g. supplying canals)	4-5	2-5	5	2	1
ARTIFICIAL RECHARGE	groundwater management	groundwater recharge	?	N/A	N/A	N/A	N/A
MORPHO-LOGICAL	lake management	hydroelectric dams	1	3	2	N/A	N/A
		water supply reservoirs	1	3	2	N/A	N/A
		flood defence dams	1	3	N/A	N/A	N/A
		Diversions	1	3	N/A	N/A	N/A
	river management	physical alteration of channel	1	4	N/A	N/A	N/A
		engineering activities	1	4	N/A	N/A	N/A
		agricultural enhancement	1	3	N/A	N/A	N/A
		fisheries enhancement	N/A	2	N/A	N/A	N/A
		land infrastructure (road/bridge construction)	1	4	N/A	N/A	N/A
		Dredging	1	5	N/A	N/A	N/A
	transitional and coastal management	estuarine/coastal dredging	N/A	N/A	N/A	4	2
		marine constructions, shipyards and harbours	N/A	N/A	N/A	4	1-2
		land reclamation and polders	1	N/A	N/A	4	1
		coastal sand suppletion	N/A	N/A	N/A	1	N/A
		new category fishing activities (physical effects (trawling) and biological effect).	N/A	N/A	N/A	4	4-5
	other	barriers & weirs	1	1	2	3-4	N/A
OTHER ANTHRO-POGENIC		litter/fly tipping	1	4	1	3	3
		sludge disposal to sea (including historic)	N/A	N/A	N/A	N/A	N/A
		exploitation/removal of other animals/plant	N/A	1-4	1	4	4
		Recreation	N/A	3-4	3 – 4	1	1
		commercial Fishing	N/A	1	3	4-5	4-5
		angling	N/A	1		2	2
		introduced species	N/A	3	4	4	4
		introduced diseases	?	3	3	4	4
		climate change	3	3	3	2	4
		land drainage	2	5	5	2	3
		*land use change					

Preliminary scoring: 1 = minimum relevance, 5 = maximum relevance, N/A = Not Applicable

Note: Degree of relevance based on known history of occurrences in Ireland (supported by monitoring information) or on expert judgement in the absence of monitoring information for water bodies where the pressure occurs.

* Denotes new pressure, which needs to be reviewed by water category experts and assigned screening score.

4. Relevant Characteristics of Overground and Underground Pathways

4.1 The 'Pathway'

Understanding and taking account of the pathway is critical to:

- Providing the link between pressures and impacts;
- Predicting the likelihood of an impact, particularly when the monitoring data are inadequate;
- Describing 'why' there could be/has been an impact;
- Enabling monitoring data to be understood and assessed;
- Enabling monitoring networks to be designed and implemented;
- Enabling 'responses' to the risk or appropriate 'measures' to be derived and implemented

There is a danger that the critical role of the characteristics of the 'environmental pathway' may be forgotten about as emphasis may tend to be put on 1) pressures and 2) monitoring data, in spite of the fact that the main reason for the conceptualisation and description element of the WFD work is to provide the necessary understanding of the functioning of water within each catchment. Encouraging greater consideration of the 'pathway' elements discourages important factors from being missed, such as: the possible role of the underground pathway in both attenuating pollutants and in transmitting pollutants to rivers; or the role of soils information/maps in helping understand runoff and predict impacts. It encourages a 3-D conceptual understanding of water in an RBD, linkages between the various components of the hydrological system, linkages between the 'cause' of problems and their 'effects', and a holistic approach to water management.

For certain pressures, such as direct discharge of effluent from sewage treatment works, the physical characteristics of the environmental pathway are not usually an issue, as the effluent is piped directly into rivers, lakes or the sea.

The 'pathway' can include the link between water categories, e.g. transitional to coastal waters.

Table 2 takes the main components of the environmental pathway and summarises their implications for surface waters and groundwater.

4.2 Pathway Susceptibility

4.2.1 Use of Susceptibility Concept in Risk Assessment

The term 'susceptibility' of a water body to pressure is used in both the IMPRESS Guidance and the UKTAG Methodology to represent the likelihood of impact. **'Susceptibility' is defined in this report as a property of the pathway.**

The characteristics of the 'environmental pathway' enable the 'susceptibility' of a pathway to a particular receptor[2] to be assessed, ranked and measured (to a certain degree at least).

It is suggested that the 'pathway susceptibility' of the main receptors to the main types of pollutants should be formulated in the form of matrices, keeping in mind the need to maintain the link with

[2] Please note that while at first glance, it may look as if 'susceptibility' is a property of the receptor (e.g. by saying *susceptibility of Pollardstown Fen*), in fact it is <u>only</u> defining the pathway to the receptor (e.g. to Pollardstown Fen). It is essential to see 'susceptibility' as a measure only of the characteristics of the pathway to a particular receptor. The 'sensitivity' of Pollardstown Fen is a separate issue. One of the difficulties is that the three terms 'vulnerability', susceptibility' and 'sensitivity' can be used interchangeably. However, 'vulnerability' has been given a specific meaning in groundwater protection schemes and will be a layer in the RBD GIS; we suggest using the term only in this way. The term 'susceptibility' has a broader meaning in UKTAG documents; we suggest using our definition for now – clearer language may be an outcome of future discussions.

layers in a GIS. While this may seem a daunting task, in practice it may only be necessary to consider a small number of representative pollutants. Three **draft** examples are given below to illustrate the process and provide a basis for further discussion.

Five categories of susceptibility are suggested: extremely high (E), high (H), moderate (M), low (L) and very low (VL). Generally, the categories of concern will be extremely high and high.

Table 2 Examples (draft) of relevant characteristics of the pathway and their implication

Component[3]	Factor	Relevant characteristic	Implication	Receptor at risk
Soil	'wet' (gley)	Low permeability	Rapid runoff (sheet flow)	SW[4] (via surface runoff)
	'dry' (Brown Earth, etc)	Moderate/high permeability	Leaching of pollutants, e.g. NO_3 and P	GW* & SW (via gw)
	Si / Ca soils	Acid buffering capacity	Poor buffering of acidic inputs	SW
	'organic'	Low permeability and high CEC	Acidic, high runoff and attenuation	SW
Subsoil	Sand/gravel	High permeability	Leaching of pollutants, e.g. NO_3	GW and SW (via gw)
	CLAY (clayey till)	Low permeability	Rapid runoff	SW (via surface runoff)
	Depth to bedrock	Bedrock at or near (<1 m) surface	a) No protection of gw b) No acceptance of rainfall in low transmissivity rock areas, with rejected recharge & rapid runoff	a) GW and SW (via gw) b) SW
		>3 m low permeability subsoil	Rapid runoff; gw protected	
Bedrock	Type of bedrock	Calcareous or siliceous	Influence on typology of rivers and lakes and buffering capacity	SW
Groundwater Vulnerability	'Extreme' and 'high'	High transit time	High leaching potential	GW and SW (via gw)
	'Low'	Low transit time and recharge; high attenuation	Minimal leaching potential & rapid runoff	SW
Aquifer flow regime	Pu, Pl and Ll	Low transmissivity; short underground flowpaths	High surface drainage	SW
	Rk, Rf, Lm	High/moderate transmissivity; long underground flowpaths	Low surface drainage; GW can act as pathway to SW GW an imp. Resource	GW and SW (via gw)
	Karst aquifers (Rk)	High velocities; point recharge, minimal attenuation	Pollutants can reach receptor quickly	GW and SW (via gw)
	Sand/gravel aquifers (Rg and Lg)	High transmissivities	Mobility of NO_3, (but not P.)	GW and SW (via gw)
Karstification	Point recharge	Presence of swallow holes	No retardation of contaminants	GW & SW (via gw)
Climate	Rainfall Evapo-transpiration	Recharge	Quantitative status Baseflow in rivers Dilution	GW SW
Topography	Slope	Gradient	Rate of runoff	SW

4.2.2 Example 1 Pathway susceptibility of a Surface Water Body to Phosphorus

Analysing the **general pathway susceptibility for phosphorus of a surface water body** requires that both the over ground and underground pathways need to be considered. Using the RBD GIS, Table 3, Table 4 and Table 5 illustrate a possible approach. The details on this approach would need input from

[3] It is intended that all the components must be present in the RBD GIS.
[4] Includes ecosystems dependent on either surface water or groundwater

relevant experts. Table 3 deals with the over ground pathway; Table 4 with the underground; and Table 5 combines the two.

Table 3 Relationship between physical setting and pathway susceptibility of surface water bodies for P. mobility by surface routes.

Physical setting	**Susceptibility** (over ground pathway)
'wet' soil	E
'Low flow' aquifers with <1 m soil/subsoil	H
Remaining areas	M, L and VL

For the **underground pathway**, soils, groundwater flow system and depth to rock data are combined, as shown in the matrix.

Table 4 Relationship between physical setting and susceptibility for P. mobility by underground routes.

Physical (hydrogeological) setting	**Susceptibility** (underground pathway)	
	'Dry' soil	**'Wet' soil**
Karst, <1 m soil/subsoil, point recharge via swallow holes	E	H
Karst, 1-3 m soil/subsoil Fissured, <1 m soil/subsoil	H	M
Remaining areas	M, L and VL	L and VL

Combining Table 3 and Table 4 gives the susceptibility of P loss by both over ground and underground routes.

Table 5 Relationship between physical setting and potential phosphorus loss.

Physical setting	**Susceptibility for P mobility**
All 'wet' soil areas (over ground) Karst areas with <1 m 'dry' soil/subsoil (underground), recharge via swallow holes	E
Karst overlain by1-3 m 'dry' soil/subsoil (underground) Fissured aquifers overlain by <1 m dry soil/subsoil (underground) Low flow aquifers with <1 m 'dry' soil/subsoil (over ground)	H
Remaining areas	M, L and VL

Note: All these areas can be derived from the RBD GIS

4.2.3 Example 2 Groundwater Bodies and General Susceptibility

In the groundwater context, there is a danger of translating pathway 'susceptibility' to just 'vulnerability'. While, depending on the pressure and circumstance, vulnerability may be the main factor, this is not always the case. The type of aquifer, and therefore the groundwater flow regime, may be relevant. For example, in a karst aquifer, overlain by thin soil/subsoil, leaching of P and transfer to a surface water receptor can readily occur. In contrast, silt and clay in a sand/gravel aquifer would attenuate P and transfer via groundwater to a surface water receptor is unlikely.

The broad susceptibility of a groundwater body (i.e. the relevant properties of the pathway) can be shown by combining vulnerability with flow regime (see Table 6 below).

Table 6 General pathway susceptibility of groundwater bodies for pressures.

Vulnerability	**Pathway Susceptibility**			
	Flow regime			
	Karst (Rk aquifers)	**Fissured** (Rf and Lm aquifers)	**Intergranular** (sand/gravel aquifers)	**Low flow[5], fissured** (Ll, Pl and Pu aquifers)
Extreme (<1 m)*	E	E	E	H
Extreme (1-3 m)*	E	E	H/M	M/H
High	H	H/M	M/H	M
Moderate	M	M	L	L
Low	L	L	L	L

* Depth to rock in bedrock aquifers or to water table in sand/gravel aquifers

4.2.4 Example 3: Susceptibility of Groundwater for Nitrate

Step 1: Use soils map to distinguish 'dry' soils from 'wet' and organic soils.
Step 2: For the 'dry' soils (i.e. free-draining) area and for parts of the country which have a groundwater protection scheme (GWPS), apply the following matrix (Table 7). For areas without a GWPS, an alternative matrix could be derived using, for instance, the subsoils map.

Table 7 General pathway susceptibility of groundwater bodies for nitrate.

Groundwater Vulnerability[6]	**Pathway Susceptibility for Nitrate**			
	Flow regime			
	Karst (Rk aquifers)	**Fissured** (Rf and Lm aquifers)	**Intergranular** (sand/gravel aquifers)	**Low flow[7], fissured** (Ll, Pl and Pu aquifers)
Extreme (<1 m soil/subsoil)*	E	E	E	E
Extreme (1-3 m subsoil)*	E	E	E	H
High	H	H	H	M
Moderate	M	M	M	L
Low	L	L	L	L

* Depth to rock in bedrock aquifers or to water table in sand/gravel aquifers.

---

[5] low transmissivity aquifers

[6] In low vulnerability areas, the travel time for recharge to reach the groundwater will be >10 years, pollution is unlikely and the proportion of available recharge percolating vertically will be low (<20%). In highly vulnerable areas, travel time is likely to be more than 100 days, chemical pollution can occur, but microbial pollution is unlikely and, in most circumstances, a high proportion of available recharge (>70)%) will reach groundwater. In extremely vulnerable areas, travel times will generally be less than 100 days although in the case of outcrop and shallow rock (<1 m) it will be hours to days, microbial and chemical pollution can occur, and in many circumstances, the proportion of available recharge reaching groundwater will be high (>70%).

[7] low transmissivity aquifers

5. Relevant Characteristics of Receptor

The WFD is not only risk-based, but it is receptor oriented, with the degree of risk depending not just on the pressures and the physical characteristics of the pathway, but also on the 'sensitivity' of the receptors, such as ecosystems, and their particular requirements. **'Sensitivity' is a property of the receptor.** Examples of attributes that control the sensitivity of a water body or ecosystem to pressure are given in Table 8.

Table 8 Examples of attributes influencing the sensitivity of receptors.

Attribute	Implication
Size of water body (e.g. lake) Residence time	Capacity to dilute (large bodies could be less sensitive) Assimilative capacity and loss of substrate for habitat (flushing effect in rivers)
Hydrochemistry of receptor ♦ Minerotrophic ♦ Ombotrophic ♦ Calcareous Lakes ♦ Degree of oxygenation	 ♦ Less sensitive to nutrients ♦ Sensitive to nutrients ♦ Higher buffering capacity to pH changes ♦ Sensitive species
Type of receptor (Habitat Type) ♦ Fens – General – Specific habitats (e.g. Pollardstown) ♦ Raised bogs – General – Specific habitats (e.g. soaks on Clara Bog) ♦ Freshwater spawning grounds ♦ Estuarine/Marine fish species	 – Sensitive to gw abstraction, but not to nutrients – Very sensitive to reduction in flows and groundwater table fluctuations. – Moderate sensitivity to gw abstraction – High sensitivity to gw abstraction and drainage ♦ Require minimum flows in particular river types for breeding, sensitive to siltation of spawning grounds. ♦ Sensitive to freshwater nutrient loadings, dangerous substances.
Physical characteristics of receptor ♦ Tidal range and regime ♦ River Morphology ♦ Lake hypsography	 ♦ Degree of exposure, zonation of species, salinity variation. ♦ Oxygenation, pool and riffle sequence for spawning. ♦ Light penetration, stratification, mixing.

Required sensitivity characteristics, which will be derived from characteristics used for typology, will include:

- River flow rate
- Recharge volumes
- Marine current velocities
- Groundwater flow regime
- Status of water body
- Species present
- Protected status
- Dependant ecosystems
- Proxy for lake assimilative capacity (volume, retention time)
- Lake bed material
- Extent of spawning areas

6. Combining Pressures, Susceptibility and Sensitivity

Set out below are examples of how combining pressures, susceptibility and sensitivity could be undertaken, using layers in the RBD GIS and matrices.

6.1 Example 1 Impact of Groundwater abstractions.

Table 9 Relationship between the risk to a groundwater body and groundwater abstraction.

Table like this for each GW Body	***to be trialled**
2015 GWABS Impact (as % of LTA Recharge)*	**GW Body Balance**
>15%	At Risk
5 to 15%	Potentially At Risk
<5%	Not at Risk

This table is taken directly from UK TAG Task 7(h) report 'Draft Guidance on the Assessment of Abstraction and Recharge Pressures on Groundwater'.

The three main inputs are:

- Pressures: Data on abstractions.
- Physical characteristics: Recharge (methodology still to be decided, but will probable be based on rainfall, subsoil type and depth and, perhaps, soil type.)
- Receptor: Groundwater body, rivers, lakes.

The matrix shows that if average annual abstraction is >15% of available recharge, the groundwater body and associated surface water bodies are 'at risk'. The figures are based on studies undertaken by EA hydrogeologists and their expert judgement. Guidance from these experts will be beneficial to us in Ireland. However, it can be argued that thresholds in Ireland could be higher because a) potential recharge is higher than, for instance, in the SE of England, and b) our recharge is more dependable (fewer/shorter droughts).

If the receptor was a very sensitive ecosystem, such as at Pollardstown Fen, where a habitat is highly dependent on groundwater flows to the fen and to the associated groundwater levels and gradients in the vicinity of the fen, the matrix could change to that shown in Table 10.

Table 10 Relationship between the risk to a sensitive habitat and groundwater abstraction.

Groundwater abstraction* as a % of recharge in catchment of ecosystem	**Risk classification of ecosystem**
>5% (based on a discussion with Paul Johnston)	'at risk'
<5%	'not at risk'

* At Pollardstown, it is a reduction in flow caused by road drainage that is the principal pressure.

6.2 Example 2 Broad approach for linking pressures with susceptibility

Table 11 illustrates how the susceptibility can be linked to pressures to provide the 'risk' categories. The magnitude of the pressure, in this case ranging from High to Low, may reflect intensity of production, stocking density or some other measure. These thresholds, e.g. between High and Moderate, will need to be developed by expert groups. The factors which are relevant to the 'susceptibility' will depend on the characteristics of the pressure (e.g. P has different mobility from NO_3). For some pressures, 'susceptibility' might be equivalent to groundwater 'vulnerability'.

Table 11 Illustration of risk classification.

Magnitude of Agricultural Pressure	***Pathway Susceptibility for Nitrate (from Table 7)**			
	E	**H**	**M**	**L, VL**
High	'at risk'	'at risk'	'potentially at risk'	'not at risk'
Moderate	'potentially at risk'	'potentially at risk'	'not at risk'	'not at risk'
Low	'not at risk'	'not at risk'	'not at risk'	'not at risk'

*Shading denotes that pressure may represent a significant risk to status.

In the case of groundwater this is the final risk matrix. The sensitivity of the receptor will not apply in this case because all groundwaters are deemed sensitive due to their potential use for abstraction. For surface waters, there will be a further table to integrate the sensitivity of the receptor. Examples 3 and 4 below present such a case for two pressures on lakes. Figure 4 emphasises the need to integrate all three elements (pressure magnitude, pathway susceptibility and receptor sensitivity) into the risk assessment. For rivers, lakes, transitional and coastal waters all three 'axes' will need to be addressed.

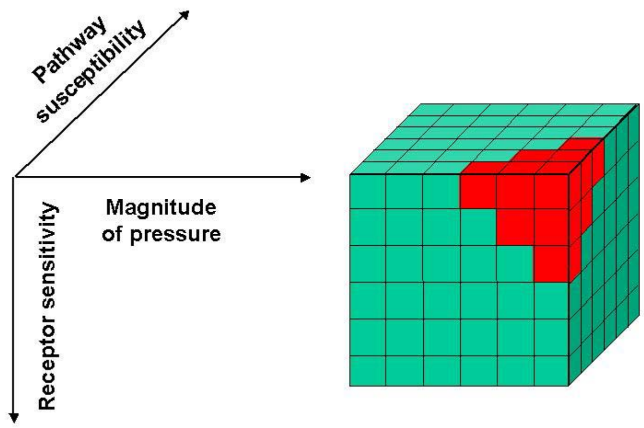


Figure 4 Diagrammatic representation of the integration all three elements of risk assessment

6.3 Example 3 Combining Pressures, Susceptibility and Sensitivity of Lakes to Total P.

In the following example, the pathway susceptibility of phosphorus to lakes is derived from Table 5. This results in three degrees of susceptibility: E, H and M/L/VL. Using these susceptibilities of P loss from soil to water we can combine pressures to give Table 12, which identifies the risk of pressures impacting on a receptor. In this case a range of Total P concentrations are used to categorise the magnitude of the pressure.

Table 12 Combining pressure and pathway susceptibility for lakes with respect to phosphorus

Pressure (Total P)	Phosphorus Pathway Susceptibility (from Table 5)		
	E	**H**	**M/L/VL**
High (>20μg l^{-1})	Very High threat	High threat	High threat
Moderate (10 – 20μg l^{-1})	Very High threat	High threat	Moderate threat
Low (<10μg l^{-1})	High threat	Moderate threat	Low threat

Following on from this, Table 13 endeavours to combine the identified risk of a pressure impacting on a receptor (i.e. pressure + susceptibility) with the sensitivity of the receptor, in this case lake trophic status. In this way all three elements of the risk assessment (pressure, pathway, receptor) are combined.

Table 13 Final risk assessment matrix combining pressure, pathway susceptibility and the sensitivity of the receptor (in this case lake trophic status).

Receptor Sensitivity (lake trophic status)	Relative threat from integration of Pressure Magnitude & Pathway Susceptibility (derived from Table 12)			
	VERY HIGH	**HIGH**	**MODERATE**	**LOW / V. LOW**
Oligotrophic	'at risk'	'at risk'	'potentially at risk	'not at risk'
Mesotrophic	'potentially at risk	'potentially at risk	'not at risk'	'not at risk'
Eutrophic	'not at risk'	'not at risk'	'not at risk'	'not at risk'

6.4 Example 4 Combining Pressures, Susceptibility and Sensitivity of Lakes to acid inputs.

In this example the risk posed by acid inputs to lakes through acid deposition is assessed. Assumptions include that acid deposition to lakes will be driven largely by the interception of rainfall by conifer plantations and subsequent runoff to river and lakes. The degree to which lakes are impacted by acidic waters will largely depend on their alkalinity, which reflects calcareous geology and subsoils in the catchment. This can be calculated as per Table 5 and for argument sake will result in three run-off risk categories; High, Moderate and Low (see Table 14).

Table 14 Pathway Susceptibility for acid deposition.

Physical Setting	Pathway Susceptibility for acid deposition
High runoff risk	High
Moderate runoff risk	Moderate
Low runoff risk	Low

As introduced in Chapter 3, the magnitude of the pressure is determined by the presence or absence of conifer plantation in the catchment. In this case, highest risk is taken to be catchments with greater than 10% conifer cover. Table 15 then combines these pressure thresholds with the pathway susceptibility risks.

Table 15 Combining pressure and pathway susceptibility for acid deposition in lakes

Pressure (Percentage of conifer cover)	Acid Deposition Pathway Susceptibility		
	HIGH	**MODERATE**	**LOW**
>10 %	V High Threat	High Threat	Moderate Threat
<10	High Threat	Moderate Threat	Low Threat
0%	Moderate Threat	Low Threat	Very Low Threat

Following on from this, Table 16 endeavours to combine the identified risk of a pressure impacting on a receptor (i.e. pressure + susceptibility) with the sensitivity of the receptor, in this case lake alkalinity. In this way, all three elements of the risk assessment (pressure, pathway, receptor) are combined. Highest risk to a lake water body will occur where alkalinity is low, where there is the presence of conifer plantation

Table 16 Final risk assessment matrix combining pressure, pathway susceptibility and the sensitivity of the receptor (in this case lake alkalinity).

Receptor Sensitivity (Alkalinity)	**Relative threat from integration of Pressure Magnitude & Pathway Susceptibility (derived from Table 15)**			
	VERY HIGH	**HIGH**	**MODERATE**	**LOW**
Low Alkalinity (<10 mg l^{-1} $CaCO_3$)	'at risk'	'at risk'	'potentially at risk	'not at risk'
Moderate Alkalinity (10-20 mg l^{-1} $CaCO_3$)	'potentially at risk	'potentially at risk	'not at risk'	'not at risk'
High Alkalinity (>20 mg l^{-1} $CaCO_3$)	'not at risk'	'not at risk'	'not at risk'	'not at risk'

7. Monitoring Data and Information on Known Impacts

7.1 Introduction

Monitoring data exist to varying degrees of adequacy. In this report, monitoring and monitoring data are placed in a broad risk assessment context, which requires analysis and understanding of the relationships and linkages between pressures, environmental pathways and impacts. Where the data are adequate, they are a critical component of the Methodology. Firstly, they are the major factor in determining the risk category of the water body; secondly, they can provide threshold values to validate pressure and impact assessments.

7.2 Thresholds for ecological status boundaries in surface waters

For surface waters, thresholds based on monitoring data will be essential for setting ecological status boundaries. Whilst these are still evolving and will not be complete until after the Intercalibration exercise in 2006, preliminary boundary thresholds may be used for this purpose.

In Appendix B Jim Bowman presents a draft paper on suggested ecological criteria boundaries for High/Good status and for Good/Moderate status to be used for the Intercalibration testing exercise. These threshold values may be used in the risk methodology to identify water bodies are below Good status and therefore 'at risk' and validate the pressure analysis. They may also be used to identify water bodies that are High status and therefore perhaps a sensitive receptor.

For rivers the Intercalibration exercise will rely on the existing Q-system, where the High/Good boundary will be Q4-5 and the Good/Moderate boundary will be Q3-4 (pers comm., Mr Kevin Clabby, EPA).

Similar preliminary ecological status boundaries are required for river and transitional/coastal waters.

7.3 Thresholds for chemical status in groundwaters

Progress has been made through the publication by EPA of Interim Guideline Values (IGV) (Keegan, 2003) for the protection of groundwater.

In this document the Author proposes, "In the absence of published criteria for good groundwater chemical status and to provide a consistent framework for the characterisation of groundwaters in Ireland, the EPA is now proposing a list of interim guideline values (IGVs) for groundwater. The values are to be used to assist with the characterisation of groundwater bodies and to establish the need for additional investigations or further actions in the event of the guideline values being exceeded."

Where monitoring data is available, these IGVs will assist in identifying bodies of groundwater that are 'at risk' and help validate the pressures analysis.

This report sets out: *"a methodology for assessing groundwater chemical status and assigning either 'good' or 'poor' groundwater status to a groundwater body. The application of this methodology will provide a consistent basis for assessing groundwater status throughout the country. This document should be viewed as an Interim Report based on the best available information at the time of publication and it may be subject to review following the adoption of the new Groundwater Directive."* This approach is summarized below in Figure 5 (Figure 4.1 from original document).

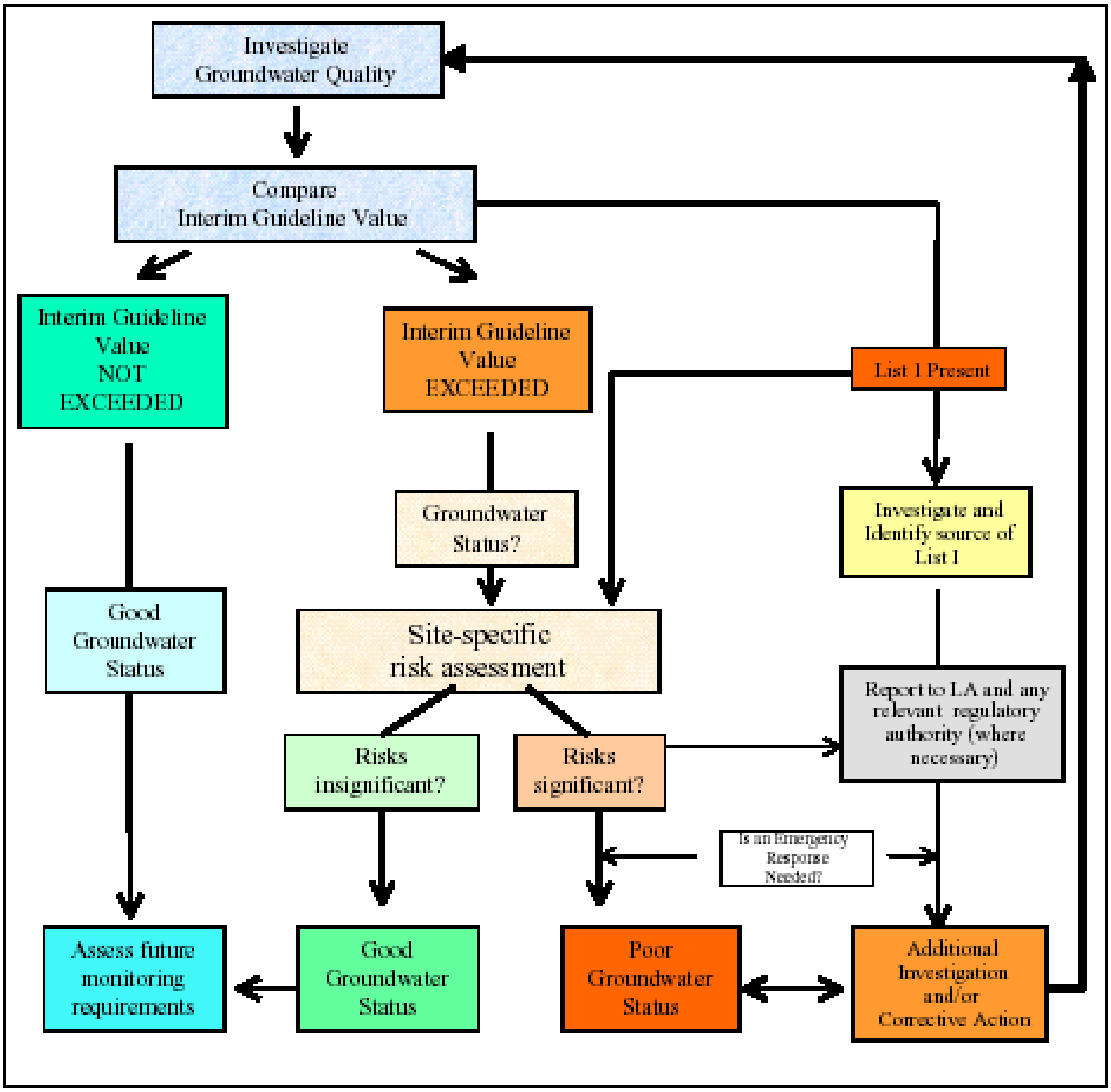


Figure 5 Proposed methodology for assessing groundwater quality (from Keegan, 2003).

8. Main Stages in Pressures and Impacts Assessment

Table 17 Summary of main stages in pressure and impact assessment.

Step[8]	**Description**
1	Delineate and undertake evaluation and description of water bodies
2	Develop a 'conceptual understanding/model' of the river basin as a 3-dimensional entity, where emphasis is placed on the interconnection and interdependencies between the various components of the water cycle.
3	Identify and delineate water bodies to be assessed (surface water, lakes, transitional, coastal and groundwater). **These water bodies may subsequently be sub-divided on completion of the pressure and impact analysis.**
4	Review existing monitoring data to determine whether there are appropriate indicators to determine whether the water body is 'at risk' or not. Draw conclusions on the value and relevance of the data, and highlight gaps.
5	Obtain and incorporate relevant GIS layers on the physical characteristics of the RBD (e.g. soil, aquifers, etc.)
6	Develop 'susceptibility' matrices for each water body type for the main types of pollutants
7	Map and evaluate known impacts, e.g. on hydromorphology.
8	Obtain relevant available information on pressures and activities that are likely to pose a risk to the status of a water body. Install info. in RBD GIS.
9	**Group all pollutants into 'pollutant types'.** **Develop general threshold values for particular pressure magnitudes and 'pollutant types', in the form of matrices.**
10	Evaluate and report on 'sensitivity' of receptors, particularly ecosystems.
11	Develop threshold values for chemical and ecological parameters that indicate the 'risk' categories.
12	Combine relevant pressures, susceptibility and sensitivity in the form of matrices for both water bodies and ecosystems.
13	Apply matrices to RBD GIS.
14	Use available monitoring data to refine the threshold values and the 'risk' conclusions. If necessary, re-evaluate and amend matrices developed under previous steps.
15	For each water body, conclude whether 'at risk', 'not at risk' or 'potentially at risk'.
16	Undertake 'further characterisation' on bodies 'at risk' and 'potentially at risk'.

8 Some of these steps will be undertaken simultaneously and can be in a different order.

9. Members of the Working Group on Groundwater

Organisation	Representative(s)
Geological Survey of Ireland (GSI)	Donal Daly (Convenor) Geoff Wright Vincent Fitzsimons Coran Kelly Taly Hunter Williams Monica Lee
Camp Dresser McKee (CDM)	Henning Moe
Compass Informatics Ltd.	Paul Mills
Department of the Environment, Heritage and Local Government (DEHLG)	Pat Duggan Jim Ryan (NPWS) Aine O'Connor (NPWS)
Environment and Heritage Service/ Geological Survey of Northern Ireland (EHS/GSNI)	Peter McConvey
Environmental Protection Agency (EPA)	Margaret Keegan Micheal McCarthaigh
Kirk McClure Morton (KMM)	Grace Glasgow Kieran Fay
O'Callaghan Moran (OCM)	Sean Moran Gerry Baker
O'Neill Groundwater Engineering (OGE)	Shane O'Neill
Shannon Pilot River Basin – EPA/TCD Research Fellow	Garrett Kilroy
Southeastern River Basin District (SERBD)	Colin Byrne
Teagasc	Karl Richards
Trinity College, Dublin (TCD)	Paul Johnston Catherine Coxon

10. References

Keegan, M. (2003) *Towards setting guideline values for the protection of groundwater in Ireland*. Environmental Protection Agency, Johnstown Castle Estate, County Wexford.

Analysis of Pressures and Impacts (IMPRESS) (2002). *The key implementation requirements of the Water Framework Directive*. Policy Summary to the Guidance Document. Fifth Draft, October 2002, 151 pp.

UK Technical Advisory Group WP7a(01) (2004) *Draft Guidance on general principles for risk assessment (PR2v6.19-01-04)*, 16 pp.

11. Appendix A – Risk Criteria Tables

Contents:

Table A1. Source-Pathway-Receptor criteria for high relevance pressures in bodies of groundwater.

PRESSURE CATEGORY	SECTOR	SECTOR ACTIVITY	Groundwater *	Type of pressure	Magnitude of Pressure	Susceptibility	Sensitivity
DIFFUSE SOURCE	urban drainage (including runoff)	Airports	4	Hazardous Chemicals	Extent of area, storage & use practices	% Hardstand, soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
	agriculture diffuse	Arable, improved grassland mixed farming	3-4	Nutrients	% Land cover, stocking rates, soil P status	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support
		crops with intensive nutrient or pesticide usage or long bare soil periods (e.g. corn, potato, sugar beets, vine, hops, fruits, vegetables)	4	Nutrients	% Land cover, stocking rates, soil P status	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support
				Hazardous Chemicals	% Land cover	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		application of agricultural waste to land	3-4	Nutrients, pathogens	Stocking rates, storage deficits & soil P status	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support
	forestry	pesticide & herbicide applications	3-4	Hazardous Chemicals	FIPS/Coillte % cover, timing data	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
	other diffuse	sewage sludge recycling to land	2-4	Metals	Spread lands, volume & composition	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
				Nutrients, Pathogens	Spread lands, volume & composition	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support
POINT SOURCE	waste water	private waste water primarily domestic (septic tanks)	3-4	Nutrients, pathogens	% unsewered network	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
	industry (includes effluent & storage)	gas/petrol	4-5	Hydrocarbons, hazardous chemicals	Location of service stations & storage facilities	age/type of storage tanks, soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		Chemicals, incl. Pharmaceutical industries (organic and inorganic)	4-5	Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		pulp, paper & boards	4	Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use

Table A1. Source-Pathway-Receptor criteria for high relevance pressures in bodies of groundwater.

PRESSURE CATEGORY	SECTOR	SECTOR ACTIVITY	Groundwater *	Type of pressure	Magnitude of Pressure	Susceptibility	Sensitivity
		food processing (incl. Agric industries)	4	Nutrients	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
				Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		electronics and other chlorinated solvent users	4	Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		wood yards/timber treatment	4	Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
	Mining	active deep mine	5	Dewatering, Hazardous chemicals	Zone of influence	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
		active open cast coal site/quarry	3-4	Hazardous chemicals, Siltation	Excavation extent	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
		gas and oil exploration and production	3-4	Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
		abandoned coal (and other) mines, spoil heaps (bings),tailings dams	5	Acidic waters, Hazardous chemicals	Age, extent, waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
	contaminated land	old landfill sites	5	Hazardous chemicals, pathogens	Age, extent, construction, composition	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		urban industrial site (organic and inorganic)	5	Hazardous chemicals	Age, extent, composition, waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		rural sites (includes illegal dumps)	5	Hazardous chemicals, pathogens	Age, construction, composition	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
	agriculture point	Slurry	5	Nutrients, Pathogens	Storage facilities and capacity	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use

Table A1. Source-Pathway-Receptor criteria for high relevance pressures in bodies of groundwater.

PRESSURE CATEGORY	SECTOR	SECTOR ACTIVITY	Groundwater *	Type of pressure	Magnitude of Pressure	Susceptibility	Sensitivity
		silage and other feeds	4	Nutrients, Pathogens	Storage facilities and capacity	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
		sheep dip use	4	Hazardous chemicals	Waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		manure depots	4	Nutrients, Pathogens	Storage facilities and capacity	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, ecosystem support, drinking water use
		farm chemicals	4	Hazardous chemicals	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
	waste management	operating landfill site	4	Hazardous chemicals, pathogens	Construction, operating practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
		operating waste transfer stations, scrap yards etc.	4	Hazardous chemicals, pathogens	Storage & waste disposal practices	soil & subsoil characteristics, karstification, travel time	Aquifer flow regime, drinking water use
ABSTRACTION	reduction in flow	abstractions for agriculture, potable supply, industry, fish farms, hydro-energy, quarries/open cast coal sites, navigation (e.g. supplying canals)	4-5	Lowering of water table	Abstraction as % of recharge	Direct	Aquifer flow regime, ecosystem support, drinking water use
ARTIFICIAL RECHARGE	groundwater management	groundwater recharge	?				
OTHER ANTHRO-POGENIC		introduced diseases	?				

Table A2. Source-Pathway-Receptor criteria for high relevance pressures in river water bodies.

Pressure Category	**Sector**	**Sectoral activity**	**River**	**Type of pressure**	**Magnitude of Pressure**	**Pathway Susceptibility**	**Receptor Sensitivity**
DIFFUSE SOURCE	urban drainage (including runoff)	industrial/commercial estates	4	Nutrients	Extent of area	Runoff risk	Flow - dilution
				Siltation	Extent of area	Runoff risk	Flow - dilution
				Toxic	Extent of area	Travel time	Dilution?
		urban areas (including sewer networks)	5	Nutrients	Extent of area	Runoff risk	Flow - dilution
				Siltation	Extent of area	Runoff risk	Flow - dilution
				Toxic	Extent of area	Travel time	Dilution?
		airports	4	Nutrients	Extent of area	Runoff risk	Flow - dilution
				Siltation	Extent of area	Runoff risk	Flow - dilution
				Toxic	Extent of area	Travel time	Dilution?
	agriculture diffuse	arable, improved grassland, mixed farming	2-4	Nutrients	Land use - % area arable etc Stocking rates Soil P status	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
		crops with intensive nutrient or pesticide usage or long bare soil periods (e.g. corn, potato, sugar beets, vine, hops, fruits, vegetables)	4	Nutrients ?arable covered above?	Land use - % area arable etc	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
				Toxic	Chemical composition	Travel time	Dilution?
		over grazing – leading to erosion	4	Siltation (leading to secondary nutrient release)	Stocking rate Soil type	Catchment slope Stream flow	Flow, Status, Species present
		horticulture, including greenhouses	4	Toxic	Land use - % area horticulture Chemical composition	Travel time	Dilution?
		application of agricultural waste to land	5	Nutrients	Stocking rates Storage deficits? Soil P status	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
	forestry	coniferous plantations	4	pH	extent of coniferous plantation Soil type	Buffering capacity - Soil type? Geology? Presence of limestone	Buffering capacity - Soil type? Geology? Presence of limestone
		planting/ground preparation	5	Siltation	extent of plantation Soil type Ground slope Technique used?	Catchment slope Stream flow	Flow, Status, Species present

Table A2. Source-Pathway-Receptor criteria for high relevance pressures in river water bodies.

Pressure Category	Sector	Sectoral activity	River	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
		felling	4	Nutrients	extent of felled area	Runoff risk	Flow, Status, Species present
				Toxic	extent of felled area	Travel time	Dilution?
		fertilizer applications	1 – 4	Nutrients	extent of fertilized area	Runoff risk	Flow, Status, Species present
		drainage	4	Siltation	extent of area drained Soil type Ground slope Technique used?	Catchment slope Stream flow	Flow, Status, Species present
	other diffuse	sewage sludge recycling to land	2-4	Nutrients	Spreadlands, Volume of material	Runoff risk	Flow, Status, Species present
				Toxic	Spreadlands, Volume/material composition	Travel time	Dilution?
		atmospheric deposition	1 – 4	Nutrients	Rainfall intensity	Runoff risk	Flow, Status, Species present
POINT SOURCE	waste water	municipal waste water primarily domestic	5	Organic	PE & level of treatment	Direct	Flow, Status, Species present
				Nutrients	PE & level of treatment	Direct	Flow, Status, Species present
				Toxic	Chemical composition	Travel time	Dilution?
				Microbiological	PE & level of treatment	Direct	Flow, Status, Species present
		municipal waste water with a major industrial component	5	Organic	PE & level of treatment	Direct	Flow, Status, Species present
				Nutrients	PE & level of treatment	Direct	Flow, Status, Species present
				Toxic	Chemical composition	Travel time	Dilution?
				Microbiological	PE & level of treatment	Direct	Flow, Status, Species present
		water supply plants	5	Water supply substances	Volume of supply	Direct	Flow, Status, Species present
		storm water and emergency overflows	5	Organic	Volume	Direct	Flow, Status, Species present

Table A2. Source-Pathway-Receptor criteria for high relevance pressures in river water bodies.

Pressure Category	Sector	Sectoral activity	River	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
				Nutrients	Volume	Direct	Flow, Status, Species present
				Toxic	Chemical composition	Travel time	Dilution?
				Microbiological	Volume	Direct	Flow, Status, Species present
		private waste water primarily domestic (septic tanks)	4	Organic	PE	Proximity to watercourses? GW vulnerability composite maps	Flow, Status, Species present
				Nutrients	PE	Proximity to watercourses? GW vulnerability composite maps	Flow, Status, Species present
				Toxic	Chemical composition	Travel time	Dilution?
				Microbiological	PE	Proximity to watercourses? GW vulnerability composite maps	Flow, Status, Species present
		private waste water with a major industrial component (IPC?)	5	Organic	PE & level of treatment	Direct	Flow, Status, Species present
				Nutrients	PE & level of treatment	Direct	Flow, Status, Species present
				Toxic	Chemical composition	Dilution? Travel time	Dilution?
				Microbiological	PE & level of treatment	Direct	Flow, Status, Species present
	industry	pulp, paper & boards	4	Toxic	Chemical composition	Travel time	Dilution?
		woollens/textiles	5	Toxic	Chemical composition	Travel time	Dilution?
		food processing	4	Toxic	Chemical composition	Travel time	Dilution?
		brewing/distilling	4	Toxic	Chemical composition	Travel time	Dilution?
		wood yards/timber treatment	4	Toxic	Chemical composition	Travel time	Dilution?

Table A2. Source-Pathway-Receptor criteria for high relevance pressures in river water bodies.

Pressure Category	Sector	Sectoral activity	River	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
		leather tanning	4	Toxic	Chemical composition	Travel time	Dilution?
	mining	active open cast coal site/quarry	4	Toxic	Chemical composition	Travel time	Dilution?
				Siltation	Extent of site Material type Ground slope Technique used?	Catchment slope Stream flow	Flow, Status, Species present
		gas and oil exploration and production	4	Toxic	Chemical composition	Travel time	Dilution?
		peat extraction	4	Siltation	Extent of site Silt trap presence Technique used?	Catchment slope Stream flow	Flow, Status, Species present
				Nutrients	Extent of site Technique used?	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
	contaminated land	old landfill sites	5	Toxic	Chemical composition	Travel time	Dilution?
		urban industrial site (organic and inorganic)	4	Organic?	Chemical composition	Travel time	Dilution?
				Toxic	Chemical composition	Travel time	Dilution?
		rural sites (includes illegal dumps)	5	Toxic	Chemical composition	Travel time	Dilution?
	agriculture point	slurry farm yards???	5	Nutrients	Livestock density Storage deficits?	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
		silage and other feeds	5	Organic? (oxygen depletion)	Practices?	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
		sheep dip use and disposal	5	Toxic	Chemical composition	Travel time	Dilution?
		manure depots	4	Nutrients	Storage capacity	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present
		farm chemicals	4	Toxic	Chemical composition	Travel time	Dilution?
	waste management	operating landfill site	4	Toxic	Chemical composition	Travel time	Dilution?

Table A2. Source-Pathway-Receptor criteria for high relevance pressures in river water bodies.

Pressure Category	Sector	Sectoral activity	River	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
		application of non agricultural waste to land	5	Toxic?	Chemical composition	Travel time	Dilution?
	aquaculture	inland fish farming / watercress / aquaculture	5	Organic	Size of enterprise	Direct	Flow, Status, Species present
				Nutrients	Size of enterprise	Direct	Flow, Status, Species present
				Toxic	Chemical composition	Direct	Dilution?
ABSTRACTION	reduction in flow	abstractions for agriculture, potable supply, industry, fish farms, hydro-energy, quarries/open cast coal sites, navigation (e.g. supplying canals)	5	Physical damage	Volume as % of recharge	Direct	Flow, Status, Species present
MORPHO-LOGICAL	river management	physical alteration of channel	4	Physical damage	Extent of works Technique?	Direct	Flow, Status, Species present
		engineering activities	4	Physical damage	Extent of works Technique?	Direct	Flow, Status, Species present
		land infrastructure (road/bridge construction)	4	Siltation	Extent of works Technique?	Direct	Flow, Status, Species present
		dredging	5	Siltation	Extent of works Technique?	Direct	Flow, Status, Species present
OTHER ANTHRO-POGENIC		litter/fly tipping	4	Physical damage	Extent of activity	Direct	Dependant ecosystems
		exploitation/removal of other animals/plants	4	Physical damage	Species	Direct	Dependant ecosystems
		recreation	4	Siltation	Extent of area Soil type	Stream flow rates Catchment slope	Flow, Status, Species present
		land use change – farmland reclamation, urbanisation, afforestation	4?	General?	% of catchment area	Runoff risk or GW vulnerability composite maps	Flow, Status, Species present

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in lake water bodies.

Pressure Category	**Sector**	**Sectoral activity**	**Lake**	**Type of pressure**	**Magnitude of Pressure**	**Pathway Susceptibility**	**Receptor Sensitivity**
DIFFUSE SOURCE	agriculture diffuse	arable, improved grassland, mixed farming	4	Nutrients	Land use - % area arable etc Stocking rates	Runoff risk or GW vulnerability composite maps	Nutrient assimilative capacity??
		crops with intensive nutrient or pesticide usage or long bare soil periods (e.g. corn, potato, sugar beets, vine, hops, fruits, vegetables)	4	Nutrients ?arable covered above?	Land use - % area arable etc	Runoff risk or GW vulnerability composite maps	Nutrient assimilative capacity??
				Toxic	Chemical composition	Dilution? Travel time	Dilution?
		over grazing – leading to erosion	4	Siltation (leading to secondary nutrient release)	Stocking rate Soil type	Catchment slope Stream flow	Lake bed material – spawning area extent
		horticulture, including greenhouses	4	Toxic	Land use - % area horticulture Chemical composition	Dilution? Travel time	Dilution?
		application of agricultural waste to land	5	Nutrients	Stocking rates Storage deficits? Soil P status	Runoff risk or GW vulnerability composite maps	Nutrient assimilative capacity??
	forestry	coniferous plantations	4	pH	extent of coniferous plantation Soil type	Buffering capacity - Soil type? Geology? Presence of limestone	Buffering capacity - Soil type? Geology? Presence of limestone
		planting/ground preparation	4	Siltation	extent of plantation Soil type Ground slope Technique used?	Catchment slope Stream flow	Lake bed material – spawning area extent
		fertilizer applications	1 – 4	Nutrients	extent of fertilized area	Runoff risk	Nutrient assimilative capacity??
	other diffuse	atmospheric deposition	1 – 4	Nutrients	Rainfall intensity	Runoff risk	Nutrient assimilative capacity??
POINT SOURCE	waste water	municipal waste water primarily domestic	5	Organic	PE & level of treatment	Direct or stream inflow	Lake volume?

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in lake water bodies.

Pressure Category	Sector	Sectoral activity	Lake	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
				Nutrients	PE & level of treatment	Direct or stream inflow	Nutrient assimilative capacity??
				Toxic	Chemical composition	Dilution? Travel time	Dilution?
				Microbiological	PE & level of treatment	Direct or stream inflow	Lake volume?
		municipal waste water with a major industrial component	5	Organic	PE & level of treatment	Direct or stream inflow	Lake volume?
				Nutrients	PE & level of treatment	Direct or stream inflow	Nutrient assimilative capacity??
				Toxic	Chemical composition	Dilution? Travel time	Dilution?
				Microbiological	PE & level of treatment	Direct or stream inflow	Lake volume?
		storm water and emergency overflows	5	Organic	Volume	Direct or stream inflow	Lake volume?
				Nutrients	Volume	Direct or stream inflow	Nutrient assimilative capacity??
				Toxic	Chemical composition	Dilution? Travel time	Dilution?
				Microbiological	Volume	Direct or stream inflow	Lake volume?
		private waste water primarily domestic (septic tanks)	4	Organic	PE	Proximity to watercourses? GW vulnerability composite maps	Lake volume?
				Nutrients	PE	Proximity to watercourses? GW vulnerability composite maps	Nutrient assimilative capacity??
				Toxic	Chemical composition	Dilution? Travel time	Dilution?
				Microbiological	PE	Proximity to watercourses? GW vulnerability composite maps	Lake volume?

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in lake water bodies.

Pressure Category	Sector	Sectoral activity	Lake	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
	industry	electronics and other chlorinated solvent users	3 – 4	Toxic	Chemical composition	Dilution? Travel time	Dilution?
		wood yards/timber treatment	3 – 4	Toxic	Chemical composition	Dilution? Travel time	Dilution?
	contaminated land	old landfill sites	5	Toxic	Chemical composition	Dilution? Travel time	Dilution?
		rural sites (includes illegal dumps)	5	Toxic	Chemical composition	Dilution? Travel time	Dilution?
	agriculture point	Slurry Farm yards???	5	Nutrients	Livestock density Storage deficits?	Runoff risk or GW vulnerability composite maps	Nutrient assimilative capacity??
		silage and other feeds	5	Organic? (oxygen depletion)	Practices?	Runoff risk or GW vulnerability composite maps	Assimilative capacity??
		sheep dip use and disposal	5	Toxic	Chemical composition	Dilution? Travel time	Dilution?
		farm chemicals	5	Toxic	Chemical composition	Dilution? Travel time	Dilution?
	aquaculture	inland fish farming / watercress / aquaculture	3 – 4	Organic	Size of enterprise	Dilution?	Dilution?
				Nutrients	Size of enterprise	Dilution?	Dilution?
				Toxic	Chemical composition	Dilution?	Dilution?
ABSTRACTION	reduction in flow	abstractions for agriculture, potable supply, industry, fish farms, hydro-energy, quarries/open cast coal sites, navigation (e.g. supplying canals)	5	Physical damage	Volume as % of recharge	Direct or % of stream inflow	Volume of lake – dependant ecosystems
OTHER ANTHRO-POGENIC		recreation	3 – 4	Physical damage	Extent of activity	Direct	Dependant ecosystems
		introduced species	4	Physical damage	Species	Direct	Dependant ecosystems
		land drainage	5	Siltation	Extent of area Soil type	Stream flow rates Catchment slope	Lake bed material – spawning area extent

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in transitional water bodies.

Pressure Category	Sector	Sectoral activity	Transitional Waters	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
DIFFUSE SOURCE	agriculture diffuse	arable, improved grassland, mixed farming	4	Nutrients	Land use - % area arable etc Stocking rates	Surface runoff, river inputs, GW seepage, tidal regime	Nutrient assimilative capacity??
		crops with intensive nutrient or pesticide usage or long bare soil periods (e.g. corn, potato, sugar beets, vine, hops, fruits, vegetables)	4	Nutrients ?arable covered above?	Land use - % area arable etc	As above	Nutrient assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
		over grazing – leading to erosion	4	Siltation (leading to secondary nutrient release)	Stocking rate Soil type	As above	
		horticulture, including greenhouses	4	Toxic	Land use - % area horticulture Chemical composition	As above	Dilution?
		application of agricultural waste to land	5	Nutrients	Stocking rates Storage deficits? Soil P status	As above	Nutrient assimilative capacity??
	other diffuse	Dredge spoil disposal into surface waters	4				
		Shipping/navigation	4				
POINT SOURCE	waste water	municipal waste water primarily domestic	5	Organic	PE & level of treatment	As above or direct inputs	Water body size?
				Nutrients	PE & level of treatment	As above	Nutrient assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	PE & level of treatment	As above	Water body size?
		municipal waste water with a major industrial component	5	Organic	PE & level of treatment	As above	Water body size?
				Nutrients	PE & level of treatment	As above	Nutrient assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	PE & level of treatment	As above	Water body size?

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in transitional water bodies.

Pressure Category	Sector	Sectoral activity	Transitional Waters	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
		storm water and emergency overflows	5	Organic	Volume	As above	Water body size?
				Nutrients	Volume	As above	Nutrient assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	Volume	As above	Water body size?
		private waste water primarily domestic (septic tanks)	4	Organic	PE	As above	Water body size?
				Nutrients	PE	As above	Nutrient assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	PE	As above	Water body size?
	industry	Food processing (incl. Agri-industries)	3 – 4				
		electronics and other chlorinated solvent users	4 – 5	Toxic	Chemical composition	As above	Dilution?
		wood yards/timber treatment	4	Toxic	Chemical composition	As above	Dilution?
		Shipyards	4 – 5				
	Mining	Abandoned coal (and other) mines, spoil heaps (bings), tailings dams	1 – 4	Toxic	Chemical composition	As above	Dilution?
	contaminated land	old landfill sites	5	Toxic	Chemical composition	Dilution? Travel time	Dilution?
MORPHO-LOGICAL	Transitional and coastal management	Estuarine and coastal dredging	4	Physical disturbance & release of toxics	Areal extent		Dependant ecosystems, Dilution?
		Marine constructions, shipyards and harbours	4	Physical			
		Land reclamation and polders	4	Physical			
		Fishing activities (physical & biological effects)	4				
OTHER ANTHRO-POGENIC		introduced diseases	4				
		introduced diseases	4				
		introduced species	4	Physical damage	Species	Direct	Dependant ecosystems

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in coastal water bodies.

Pressure Category	Sector	Sectoral activity	Coastal Waters	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
DIFFUSE SOURCE	agriculture diffuse	over grazing – leading to erosion	4	Siltation (leading to secondary nutrient release)	Stocking rate Soil type	Surface runoff, currents, tidal regime, adjacent water bodies	Dependent ecosystems
		application of agricultural waste to land	5	Nutrients	Stocking rates Storage deficits? Soil P status	As above	assimilative capacity??
	forestry	coniferous plantations	4	pH	extent of coniferous plantation Soil type	As above	
		planting/ground preparation	4	Siltation	extent of plantation Soil type Ground slope Technique used?	As above	
		fertilizer applications	1 – 4	Nutrients	extent of fertilized area	As above	assimilative capacity??
	other diffuse	Dredge spoil disposal into surface waters	4-5				
		Shipping/navigation	4				
POINT SOURCE	waste water	municipal waste water primarily domestic	4	Organic	PE & level of treatment	As above or direct input	Water body size?
				Nutrients	PE & level of treatment	As above	assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	PE & level of treatment	As above	Water body size?
		municipal waste water with a major industrial component	4	Organic	PE & level of treatment	As above	Water body size?
				Nutrients	PE & level of treatment	As above	assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	PE & level of treatment	As above	Water body size?
		storm water and emergency overflows	5	Organic	Volume	As above	Water body size?
				Nutrients	Volume	As above	assimilative capacity?

Table A3. Source-Pathway-Receptor criteria for high relevance pressures in coastal water bodies.

Pressure Category	Sector	Sectoral activity	Coastal Waters	Type of pressure	Magnitude of Pressure	Pathway Susceptibility	Receptor Sensitivity
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	Volume	As above	Water body size?
		private waste water primarily domestic (septic tanks)	4 – 5	Organic	PE	As above	Water body size?
				Nutrients	PE	As above	assimilative capacity??
				Toxic	Chemical composition	As above	Dilution?
				Microbiological	PE	As above	Water body size?
	industry	electronics and other chlorinated solvent users	4	Toxic	Chemical composition	As above	Dilution?
		wood yards/timber treatment	4	Toxic	Chemical composition	As above	Dilution?
	agriculture point	Slurry Farm yards???	4	Nutrients	Livestock density Storage deficits?	As above	assimilative capacity??
		silage and other feeds	4	Organic? (oxygen depletion)	Practices?	As above	Assimilative capacity??
		sheep dip use and disposal	4	Toxic	Chemical composition	As above	Dilution?
		farm chemicals	4	Toxic	Chemical composition	As above	Dilution?
	aquaculture	inland fish farming / watercress / aquaculture / shellfish / marine cage farming	4	Organic	Size of enterprise	As above	Dilution?
				Nutrients	Size of enterprise	As above	Dilution?
				Toxic	Chemical composition	As above	Dilution?
MORPHO-LOGICAL	Transitional and coastal management	Fishing activities	4 – 5	Physical			
OTHER ANTHRO-POGENIC		Commercial fishing	4 – 5				
		introduced species	4	Physical damage	Species	Direct	Dependant ecosystems
		introduced species	4				
		Exploitation/removal of other plants/animals	3 – 4	Physical damage	Extent of activity	Direct	Dependant ecosystems
		Climate change	4				

12. Appendix B – Draft Ecological Status Boundaries for lakes

Criteria for lake site selection for the Draft Register of Intercalibration sites for Republic of Ireland.

It is estimated that there are in excess of 11,000 lakes in the Republic of Ireland. Direct chemical measurements have been performed, in the last decade, on approximately 600 lakes, while details on the phytoplankton, macrophytes and macroinvertebrates are available for about 250 of these.

The frequency of chemical sampling is variable. During the last review of water quality for the period 1998- 2000, the majority of lakes had been sampled once a year, 49 lakes had been examined three times or more during the Summer period and 30 were sampled at a frequency that allowed calculation of annual values.

Water Framework Directive Intercalibration Exercise

The Intercalibration exercise is to be confined to the two most important pressures on lakes: Nutrient loading and acid deposition and their impacts.

Pressure: Nutrient Loading for which the quality elements Phytoplankton and Macrophytes will be examined.

Pressure: Acid deposition for which the quality elements Macroinvertebrates and Fish (if available) will be examined.

Ireland will participate in Intercalibrating 5 types:

Table B.1 Intercalibration types for Ireland.

Region	Type	Altitude	Depth	Geology	Size
Northern	L-N1	*Lowland*	*Shallow*	*Moderate Alkalinity*	*Large*
		<200m asl	3 - 15m	10 - 50 mg CaCO3/l	0.5 - 5.0 km2
	L-N2	*Lowland*	*Shallow*	*Low alkalinity*	*Large*
		<200m asl	3 - 15m	<10 mg CaCO3	0.5 - 40 km2
Atlantic	*L -A1*	*Lowland*	*Shallow*	*Calcareous*	*Small*
		<200m asl	3 - 15m	>50 mg CaCO3	<0.5 km2
	L-A2	*Lowland*	*Shallow*	*Calcareous*	
		<200m asl	3 - 15m	>50 mg CaCO3	>0.5 km2
	L -A3	*Lowland*	*Shallow*	*Peat*	*Small*
		<200m asl	3 - 15m		<0.5 km2

For each of these five types we are requested to supply information on **two** sites at the high/good and good/moderate boundaries respectively giving a total of 20 sites.

As the above boundaries have not been formally set the instruction is for each Member State to set their own boundaries based on their interpretation of the normative definitions of the relevant 3 statii in Annex V of the Directive.

The following are suggested ecological criteria for setting such boundaries:

Table B.2 Lowland, Shallow Calcareous Lakes (small and large) (L-A1 and L-A2)

Quality Element	Indicators	High/Good Boundary	Good/ Moderate Boundary
Phytoplankton	Species composition	Pennate diatoms prominent in summer in diverse but small populations	Melosira spp, Stephanodiscus spp. & Cyanobacteria prominent in summer in diverse populations
	Cell Volume (annual mean)	1 mm^3/l	2 mm^3/l
	Chlorophyll Abundance (annual values)	$\overline{}$ [2.5] Max [8.0]	$\overline{}$ [8.0] Max [25.0]
Macrophytes	Species composition	*Chara* sp. prominent. Increasing amounts of *Lemna trisulca* Very little *Elodea canadensis*	Decreased amounts of: *Chara* sp. and increasing amounts of *Fontinalis antipyretica, Nuphar lutea, Potamogeton pectinatus, Potamogeton lucens* *Elodea* spp prominent filamentous algae (mostly *Cladophora*) may also be prominent
	Depth of Macrophyte Charophytes) Colonisation	6.0 m	4.0 m
Physico-Chemical	Total Phosphorus	10 mg P/m^3	20* mg P/m^3 *Phosphorus Regulations in operation in RoI require that this value should be **20 mg P/m^3**, while the OECD Classification scheme suggests 35 mg P/m^3

Table B.3 Lowland, Shallow Siliceous (Moderate Alkalinity) Lakes > 0.5 km2 (L-N1)

Quality Element	Indicators	High/Good Boundary	Good/ Moderate Boundary
Macrophytes	Species Composition	*Isoetes lacustris* *Littorella Uniflora* and *Nitella* sp.	increasing amounts of *Elodea canadensis, Potamogeton perfoliatus, Potamogeton berchtoldii* and absence of *Isoetes* sp, *Littorella* and *Nitella* sp.
Macroinvertebrate	Species Composition	Reduced numbers of acid sensitive organisms: *Baetis* spp. *Gammarus* spp, *Lymnaea peregra*	Absence of most sensitive forms

Table B.4 Lowland, Shallow Siliceous (Low Alkalinity) Lakes > 0.5 km^2 (L-N2 and L-A3)

<table>
<tr><th>Quality Element</th><th>Indicators</th><th>High/Good Boundary</th><th>Good/ Moderate Boundary</th></tr>
<tr><td>Macrophytes</td><td>Species Composition</td><td>increasing amounts of Fontinalis antipyretica, Potamogeton natans</td><td>presence of Nuphar lutea</td></tr>
<tr><td colspan="4">These lakes are typically characterised by the common occurrence of Isoetes lacustris, Littorella uniflora, Juncus bulbosus, Myriophyllum alterniflorum and Nitella sp.</td></tr>
<tr><td colspan="4">No lakes in Ireland are impacted by anthropogenic acidification sufficiently to observe a trend in macrophytes with pH. However, a natural trend is clearly evident in that Juncus bulbosus is almost exclusively confined to lakes with an alkalinity < 10 mg l^{-1} $CaCO_3$.</td></tr>
<tr><td>Macroinvertebrate</td><td>Species Composition</td><td>Reduced numbers of acid sensitive organisms: Baetis spp., Caenis sp., Lymnaea peregra, Gammarus spp</td><td>Absence of the most sensitive forms. Some of the following present: Centroptilum spp., Ecdyonurus spp, Heptagenia spp, Cloeon spp., Isoperla spp., Capnia spp, Siphlonurus spp., Tinodes spp, Sericostoma sp., Hydropsyche spp., plus</td></tr>
<tr><td colspan="4">Due to the sensitivity of certain species of littoral macroinvertebrates to acid conditions these organisms are increasingly used to measure of the impact of acidification on surface waters. A classification scheme or “acidification score index” - the Raddum Index - has been adapted to express the results. In this method species are assigned an “acidification score” or index in accordance with the following scheme of sensitivity or tolerance to acidity:

<table>
<tr><th>Category</th><th>Min. pH tolerated by species</th><th>Score</th><th>Inferred acidification impact by presence</th></tr>
<tr><td>A</td><td>5.5-6.0</td><td>1.0</td><td>None</td></tr>
<tr><td>B</td><td>5.0-5.5</td><td>0.5</td><td>Moderate</td></tr>
<tr><td>C</td><td>4.7</td><td>0.25</td><td>Serious</td></tr>
<tr><td>D</td><td><4.7</td><td>0</td><td>Severe</td></tr>
</table>

To comply with the WFD boundaries could be set based on the 90, 75, 50 and 25 percentile of the unimpacted or reference score to indicate deviation.</td></tr>
<tr><td>Fish</td><td>Species Composition</td><td>0^+ Salmo trutta present</td><td>0^+ Salmo trutta sparse or absent</td></tr>
<tr><td>Physico-Chemical</td><td>PH

ANC</td><td>6.00

<40?</td><td>5.50

<20</td></tr>
</table>