CHAPTER FIVE

GROUNDWATER QUALITY IN IRELAND

INTRODUCTION

Groundwater is an important natural resource in Ireland; both in terms of yield and water quality. It is an important source of drinking water and is utilised in food and industrial processing. Groundwater flows through and is stored in the pore spaces of sand and gravel deposits and the fractures in bedrock. If the geological deposit can yield enough water for a significant water supply then it is referred to as an aquifer. The physico-chemical properties of groundwater can be examined through the study of pumped groundwater abstractions and groundwater that seeps to the surface as springs, e.g. Figure 5.1.

Figure 5.1 Groundwater Spring Source in County Mayo

Groundwater as a Source of Drinking Water

Approximately 26 percent of the public and private drinking water supply in Ireland is provided by groundwater or spring sources (EPA, 2008a) with the latter supplying approximately nine percent of the total. In certain counties, e.g. Roscommon, the percentage is significantly higher, with groundwater providing approximately 75 percent of the drinking water (EPA, 2007).

Although treated public water supplies and public group water schemes account for approximately 85 percent of the total volume of drinking water supplied in Ireland (EPA,

2008a), the actual number of private group water schemes and small private supplies far exceeds that of public supply schemes.

The majority of private group schemes and small supplies are reliant on groundwater and spring sources and often have inadequate treatment or, in many cases, no treatment at all. This heightens the need for aquifer and source protection, pollution prevention, and the treatment of groundwater, to ensure that the quality of drinking water conforms to the requirements of the Drinking Water Regulations (S.I. 278 of 2007). Furthermore, to protect private supplies, and reduce the risk of pollution of public supplies, there needs to be adequate protection of groundwater as a resource. As groundwater may ultimately discharge from an aquifer to springs, rivers, estuaries or wetlands, these may also be adversely affected if the aquifer is polluted.

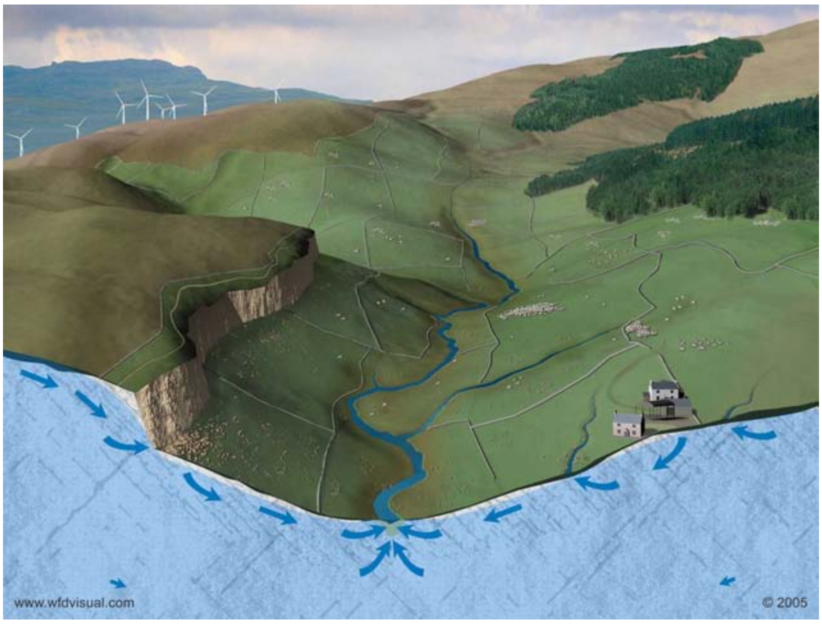


Figure 5.2 Groundwater Contributions to Wells and Surface Waters are Mainly Limited to Flows at Shallow Depths in Poorly Productive Aquifers

The interaction between groundwater and surface water is complex and the quantification of the volume of groundwater that contributes to surface water flow and its chemical composition is often difficult to calculate. Groundwater contributions to surface water flow vary; often the deep groundwater contribution is less than 5 percent in the low yielding 'poorly productive' aquifers (Figure 2), however, the overall contribution may be higher if the shallow 'top of the rock' contribution is included, resulting in an overall contribution of

less than 30 percent in these aquifers. In contrast, in the more productive aquifers (Figure 5.3), e.g. karstified limestone or sand and gravel aquifers, the contribution may be up to 80 or 90 percent.

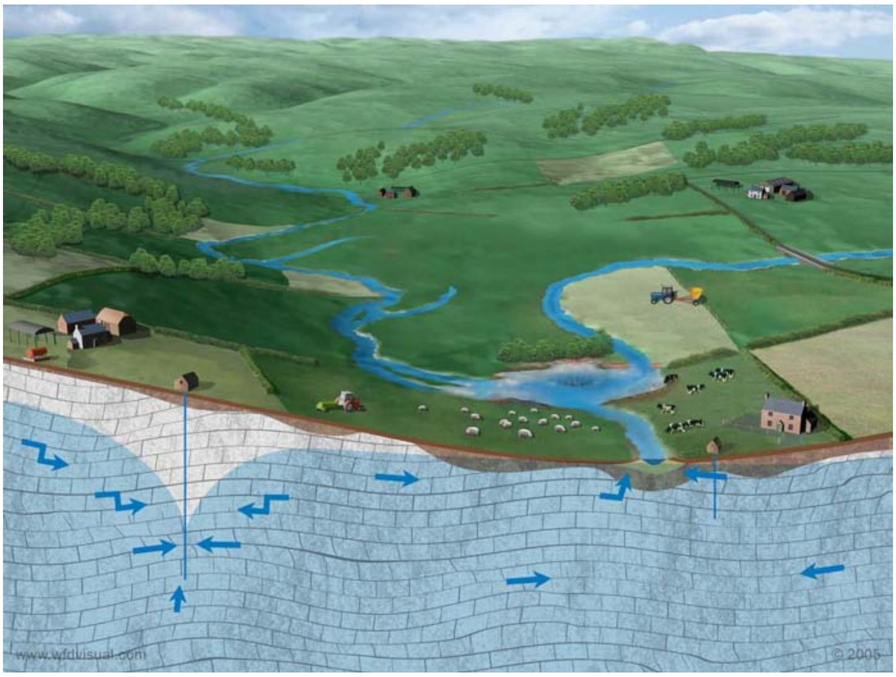


Figure 5.3 Groundwater Provides a Significant Contribution to Wells and Surface Waters in Productive Aquifers

Figure 5.4 Fissures in a Limestone Bedrock Aquifer in County Kilkenny

Bedrock aquifers in Ireland have fissure permeability only, where water flow is predominantly through fissures or fractures (e.g. Figure 5.4) and not through pore spaces in the rock itself; thus, any contaminants present in the groundwater undergo minimum attenuation. The sand and gravel aquifers that underlie approximately 2 percent of the country are the only aquifers with intergranular permeability. All aquifers are protected by the overlying soil and subsoil, where some attenuation of contaminants may occur; therefore variation in subsoil type, and thickness, is important when characterising the vulnerability of aquifers to contamination.

A large proportion of the productive aquifers in Ireland are karstified limestone (Map 5.1). Karst landscapes develop in rocks that are readily dissolved by water, e.g. limestone (composed of calcium carbonate), and typically conduit, fissure and cave systems develop underground (Geological Survey of Ireland, 2000).

Groundwater Directive

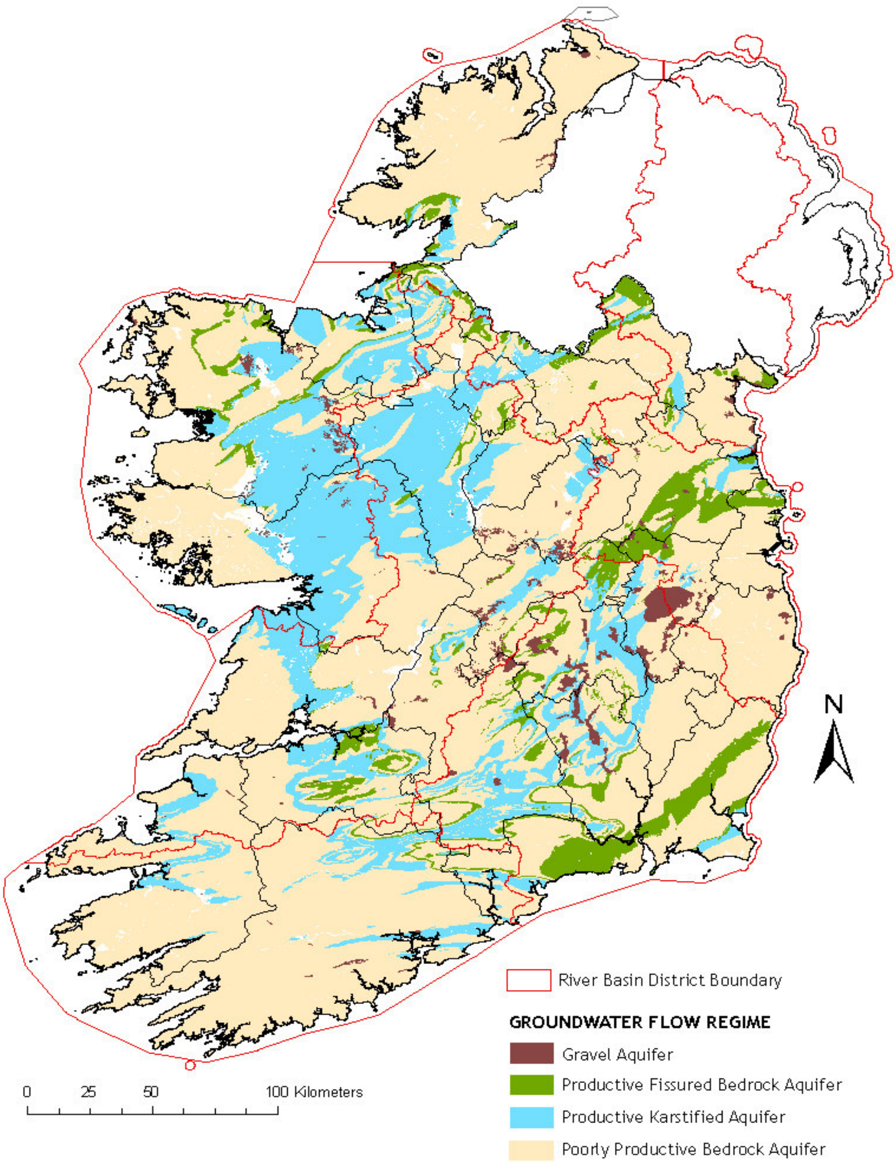
The forthcoming EU Directive on 'the Protection of Groundwater Against Pollution and Deterioration' (Groundwater Daughter Directive) provides the detail on the means by which the Water Framework Directive (WFD) requirements to prevent and control groundwater pollution (Article 17) are met. In particular, it sets out criteria and procedures for assessing groundwater chemical status and includes identification of any significant and sustained upward trends and the reversal of such trends where they are posing an environmental risk. The Directive outlines the basis for establishing measures to prevent or limit the input of pollutants into groundwater. Account must be taken not only of the need to protect groundwater for environmental reasons, but also for human health reasons.

While the Groundwater Daughter Directive emphasises the relevance of protecting groundwater, so that the environment and groundwater-dependent ecosystems are not impacted detrimentally, it also broadens the remit of the WFD, by mentioning human health as an issue that must be considered.

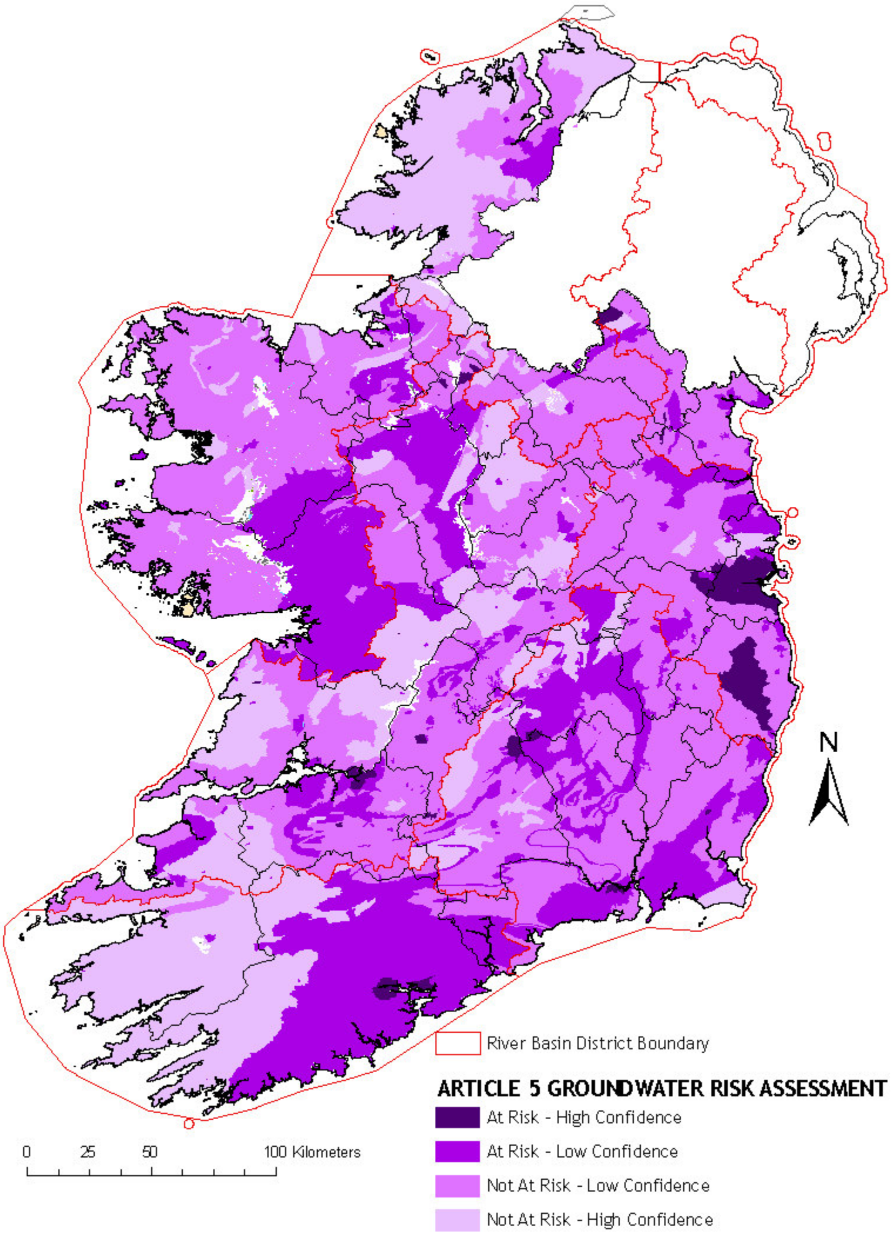
WFD Risk Characterisation

The WFD Article 5 risk assessment (EPA, 2005) indicated that approximately 50 percent of the groundwater bodies in Ireland are at risk of failing to meet the objectives of the WFD due to anthropogenic pressures on water quality (see Map 5.2). The majority of these

groundwater bodies are associated with areas that are impacted by point source pressures and are generally small, e.g. landfill or contaminated land sites. Consequently, these groundwater bodies represent only 16 percent of the countries area.



Map 5.1 Simplified Groundwater Flow Regime Map of Ireland (Source: GSI)



Map 5.2. Article 5 Groundwater Quality Risk Assessment

The groundwater diffuse pressure risk assessment indicated that nutrient pressures from agricultural activities (including livestock farming, arable activities and intensive enterprises) and usage of dangerous substances, e.g. agrochemicals, are the most widespread and nationally significant anthropogenic pressure on groundwater. Nitrates were identified as being the most significant pollutant when considering groundwater as the receptor. The groundwater pathway for delivering phosphate loading to surface waters receptors may also be significant in some areas, such as extremely vulnerable bedrock areas. Point source

pressures, e.g. mines, quarries or landfills were considered, in most instances, unlikely to exert a significant influence on an entire groundwater body, as groundwater bodies are relatively large units (generally over fifty square kilometres).

For more information on the Article 5 characterisation report, go to www.wfdireland.ie

Groundwater Monitoring

A new groundwater monitoring programme has been developed to improve knowledge of groundwater quality, and the links between groundwater and the ecological health of associated receptors. Monitoring data will provide the basis for the assessment of groundwater status in Ireland. Once the status of groundwater has been established, where necessary, appropriate measures will be implemented to protect groundwater, including water abstracted for public and private drinking water supplies and surface water and ecological receptors that are fed by groundwater.

The location of groundwater monitoring points has been determined by assessing the requirements for achieving a network that is representative of the variations in hydrogeology and anthropogenic pressures across a groundwater body, i.e. the ‘average’ concentrations of pollutants from a representative network of monitoring points should reflect the ‘average’ concentrations for those pollutants across the whole groundwater body.

Approximately 65 percent of the bedrock aquifers in Ireland are classed as ‘poorly productive’ and are generally unable to yield significant quantities of groundwater for abstraction, although high yields can be obtained at some locations, such as in fractured fault zones. As these aquifers are generally unable to support significant yields, the contributing area to the wells are often relatively small and only reflect a small proportion of the overall groundwater body. Monitoring networks in these aquifers have been developed to focus on groundwater bodies where there are sensitive wetlands or streams, with a small number of monitoring points installed in some of the different poorly productive bedrock aquifer types , e.g. granites.

Monitoring data from selected compliance monitoring sites at IPPC licensed activities, will be utilised for the assessment of point source pressures within groundwater bodies. The compliance monitoring data may be supplemented by additional monitoring in the future,

e.g. where the monitoring is deemed to be inadequate for WFD purposes or for point source pressures that are not part of the compliance monitoring network, e.g. historical waste dumps.

GROUNDWATER QUALITY IN IRELAND

In Ireland, limestone bedrock and limestone dominated subsoil are common and consequently groundwater is often hard, containing high concentrations of calcium, magnesium and bicarbonate. In areas where sandstone or volcanic rocks dominate, softer water is normal. Elevated concentrations of certain ions can occur naturally and may lead to water quality problems, e.g. iron, manganese, sulphate and arsenic, and sodium and chloride in aquifers near coasts.

Consequently, it is important to consider natural hydrochemical variations when interpreting the analysis from groundwater quality monitoring programmes and assessing whether groundwater is polluted.

Natural Background Conditions

The natural quality of groundwater varies as groundwater flows from recharge areas, e.g. elevated topography, to discharge areas, e.g. springs or rivers. The groundwater chemistry may change as it passes through soils, subsoils or rocks with different mineralogy. The groundwater chemistry is also continually being modified by the influence of human activity, whether that is through changes in groundwater flow, caused by groundwater abstraction, or the introduction of anthropogenic substances. Therefore, the characterisation of the natural groundwater chemistry is a critical component of any groundwater management or protection strategy, i.e. it is important to know what the background or natural chemical composition of the groundwater before determining if there is an impact from anthropogenic activities.

This has particular relevance in relation to the WFD, which requires that Member States set environmental standards or threshold values for pollutants that are having a harmful impact on water quality. Monitoring data will be assessed in relation to these values and where the groundwater quality is deemed to be in breach of these values and is having a detrimental impact on an associated receptor, e.g. a drinking water abstraction or a river, the groundwater body may be deemed to be at poor status and measures may be required to

improve the groundwater quality. Therefore, knowledge of natural or un-impacted groundwater quality is an important starting point, if anthropogenic impacts on water quality are going to be assessed with an acceptable degree of confidence.

Assessing Natural Background Concentrations

The presence of purely anthropogenic substances, e.g. hydrocarbons or pesticides, clearly indicates departure from natural conditions. However, for many solutes that can be derived from either natural or pollution sources (e.g. nitrate or phosphate), the distinction is not as clear cut. It could be argued that the natural concentrations of these solutes should reflect conditions during pre-industrial times. However, water quality data are rarely available from these times.

An ideal starting point for assessing natural conditions are to sample groundwater that has been largely un-impacted by human activity. Agriculture has the most widespread impact on groundwater quality, particularly where more intensive practices take place or where diffuse agro-chemicals are introduced. Urbanisation and industrialisation may have significant localised impacts on groundwater quality, and may impact on the groundwater flow regime in an area, e.g. through the introduction of artificial surfaces, such as concrete. Changes to the atmospheric conditions in urban and industrial areas may also alter the chemistry of the water recharging an aquifer and the direct input of water and/or pollution from leaking pipes may also have an impact on groundwater chemistry.

Natural Background Concentrations in Ireland

As part of the WFD Article 5 Risk Characterisation, the EPA commissioned a study (see EPA, 2005 for further information) to establish a methodology to determine the Natural Background Level (NBL) concentration for a range of parameters. NBL values are indicative of natural conditions, beyond which it is likely that the groundwater has been polluted to some degree. The NBLs are not environmental standards; they are a means of providing a datum when assessments are being made to determine if there are anthropogenic impacts on groundwater quality. It is also important to recognise that natural groundwater hydrochemistry may vary within an individual aquifer.

Due to limited historical data, the most applicable method for the assessment of NBLs in Ireland was the use of data from relatively un-impacted monitoring locations. Only water

quality data from representative monitoring locations were considered for the assessment, and only those water quality samples with less than +/- 10% error in their chemical ionic balance were included. Additionally, only monitoring locations in areas with low groundwater vulnerability and/or low anthropogenic pressures were considered for the study.

Aquifer lithology may influence the groundwater chemistry, however, it was concluded that the NBL for certain parameters are not significantly influenced by lithology (OCM, 2007). These are referred to as 'Global' parameters and the NBL and median concentrations are shown in Table 5.1.

Due to limited datasets and a large number of sample concentrations that were lower than the analytical detection limit, it was not possible to derive NBLs for Ammonium, Nitrite, Total Phosphate, Arsenic, Antimony, Beryllium, Boron, Cadmium, Cobalt, Mercury, Lead, Molybdenum, Strontium, Uranium and Radon.

Table 5.1 Global Parameter NBLs (OCM, 2007)

Parameter	Bedrock Type	10^{th} Percentile / Lower NBL	Median	90^{th} Percentile / Upper NBL
Nitrate (mg/l NO_3)	Global	0.31	3.3	9.2
Orthophosphate (µg/l)	Global	2	6	20
Chloride (mg/l)	Global	12	18	24
Sulphate (mg/l)	Global	2.8	11	37
Iron (µg/l)	Global	18	25	130
Manganese (µg/l)	Global	1	8	32
Zinc (µg/l)	Global	1.5	8	55
Chromium (µg/l)	Global	0.5	2	8
Copper (µg/l)	Global	0.5	2.5	23
Barium (µg/l)	Global	5	38	162
Fluoride (mg/l)	Global	0.05	0.1	0.21
Nickel (µg/l)	Global	0.5	1.7	8

Where aquifer lithology was thought to impact on the natural groundwater chemistry, the NBLs were assessed for a small group of different bedrock types. The NBL and median

concentrations for parameters where aquifer lithology influences the NBL are shown in Table 5.2.

Table 5.2 Bedrock Influenced Parameter NBLs (OCM, 2007)

Parameter	Bedrock Type	10th Percentile / Lower NBL	Median	90th Percentile / Upper NBL
Electrical Conductivity (µS/cm)	Lower Palaeozoic	448	572	800
	Devonian	137	191	228
	Karst	445	544	731
	Mixed	377	595	727
	Granite	40	67	129
	Confined - Limestones	668	721	750
	Confined - Sandstones	422	449	520
pH	Lower Palaeozoic	6.6	7.4	8.4
	Devonian	5.3	6.3	7.4
	Karst	7	7.3	7.7
	Mixed	6.7	7.3	7.6
	Granite	5.6	6.1	6.7
	Confined - Limestones	7.3	7.5	7.7
	Confined - Sandstones	7	7.3	7.8
Potassium (mg/l)	Lower Palaeozoic	0.5	2	6
	Devonian	0.4	1.1	2
	Karst	0.8	1.6	2.8
	Mixed	0.7	1.6	3.8
	Confined - Limestones	1.2	1.9	2.5
Sodium (mg/l)	Lower Palaeozoic	8	19	37
	Devonian	7.7	9	18
	Karst	7	11	19
	Mixed	9.6	13	26
	Confined - Sandstones	7	18	37
Calcium (mg/l)	Lower Palaeozoic	68	82	96
	Devonian	3.8	17	33
	Karst	54	89	132
	Mixed	39	86	111
	Confined - Limestones	45	84	107
	Confined - Sandstones	34	47	66

Magnesium (mg/l)	Lower Palaeozoic	9	20	67
	Devonian	2.2	3.3	8
	Karst	4.1	8.4	14
	Mixed	3.4	9.9	24
	Confined - Limestones	14	23	35
	Confined - Sandstones	9	22	40
Alkalinity (mg/l)	Lower Palaeozoic	220	304	435
	Devonian	13	73	93
	Karst	174	246	342
	Mixed	91	236	308
	Confined - Limestones	187	290	398
	Confined - Sandstones	170	227	278
Total Hardness (mg/l)	Lower Palaeozoic	219	311	446
	Devonian	21	73	98
	Karst	182	258	364
	Mixed	79	242	364
	Confined - Limestones	200	333	382
	Confined - Sandstones	180	212	237

The EPA plans to regularly review the assessment and if necessary amend the NBLs as more data become available.

The availability of NBL data will assist in the establishment of standards / threshold values and should reduce the risk of miss-classifying the status of groundwater bodies and therefore prevent the introduction of unnecessary remedial measures.

APPRAISAL OF EXISTING GROUNDWATER DATA

Historically, the EPA has monitored groundwater quality at a number of public and private wells and springs across the country. The development of revised monitoring networks in 2007, to meet the requirements of the WFD, has resulted in a number of the historical monitoring points being dropped from the EPA's Groundwater Monitoring Programme. Additional monitoring points, that are considered to be representative of the physical aquifer

characteristics and anthropogenic pressures on groundwater, have been added to the Programme.

The appraisal of data in this Chapter focuses on monitoring points selected for the WFD Groundwater Monitoring Programme. Therefore historical data from monitoring points that are no longer in the WFD Programme have not been included in the data analysis. Data are presented for the period 2004-2006, and, for comparison, historical data from 1995-2003 are presented, again only using data from the same set of WFD monitoring points.

Groundwater Quality

The data presented have been gathered by the EPA and have been supplemented by data gathered in the South Eastern River Basin District, as part of their pilot groundwater risk assessment in 2004-05. The data are presented for parameters that are indictors of anthropogenic pollution (Ammonium, Nitrate, Phosphate and Faecal Coliforms) and comparison is made with the appropriate threshold values, standards and principles that will be utilised for WFD classification for these parameters, e.g. the key phosphate threshold concentration in groundwater will be derived from the environmental standard for surface water receptors.

It was considered that a minimum of four samples is required to determine an average concentration at a monitoring location. An exception to this approach was made in the case of the bacteriological analysis where each individual sample has been considered in the assessment, including those from sampling locations at which less than four samples were taken. This is in acknowledgement of the fact the presence of a single faecal coliform in a drinking water supply is a breach of the Drinking Water Regulations (S.I. 278 of 2007). Therefore, for the faecal coliform assessment, all samples at a monitoring point have been considered; although, absence of faecal coliforms at a monitoring location has only been assumed when at least four samples have given zero counts.

Ammonium Microbiological reduction of nitrogen-containing compounds generally results in very low background concentrations of ammonium in natural waters. Ammonium has a low mobility in soil and subsoil. Its presence in groundwater much above 0.15 mg/l N is usually indicative of a nearby source of organic pollution, such as effluent from farmyard manure, slurry and dirty water or from on-site wastewater treatment systems (such as septic

tanks or similar systems), although high ammonium concentrations may be encountered naturally, e.g. in peat land areas. Under the Drinking Water Regulations, the MAC of ammonium is 0.23 mg/l as N.

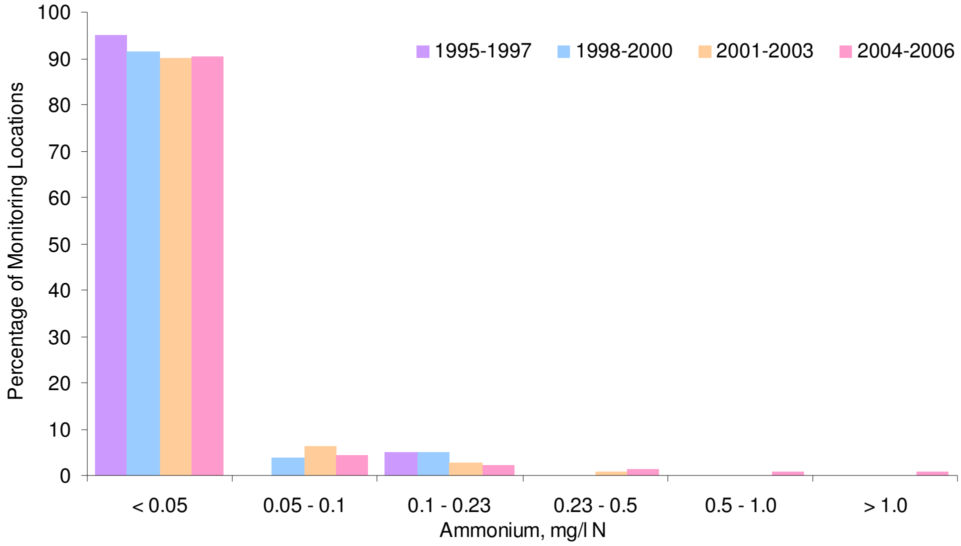
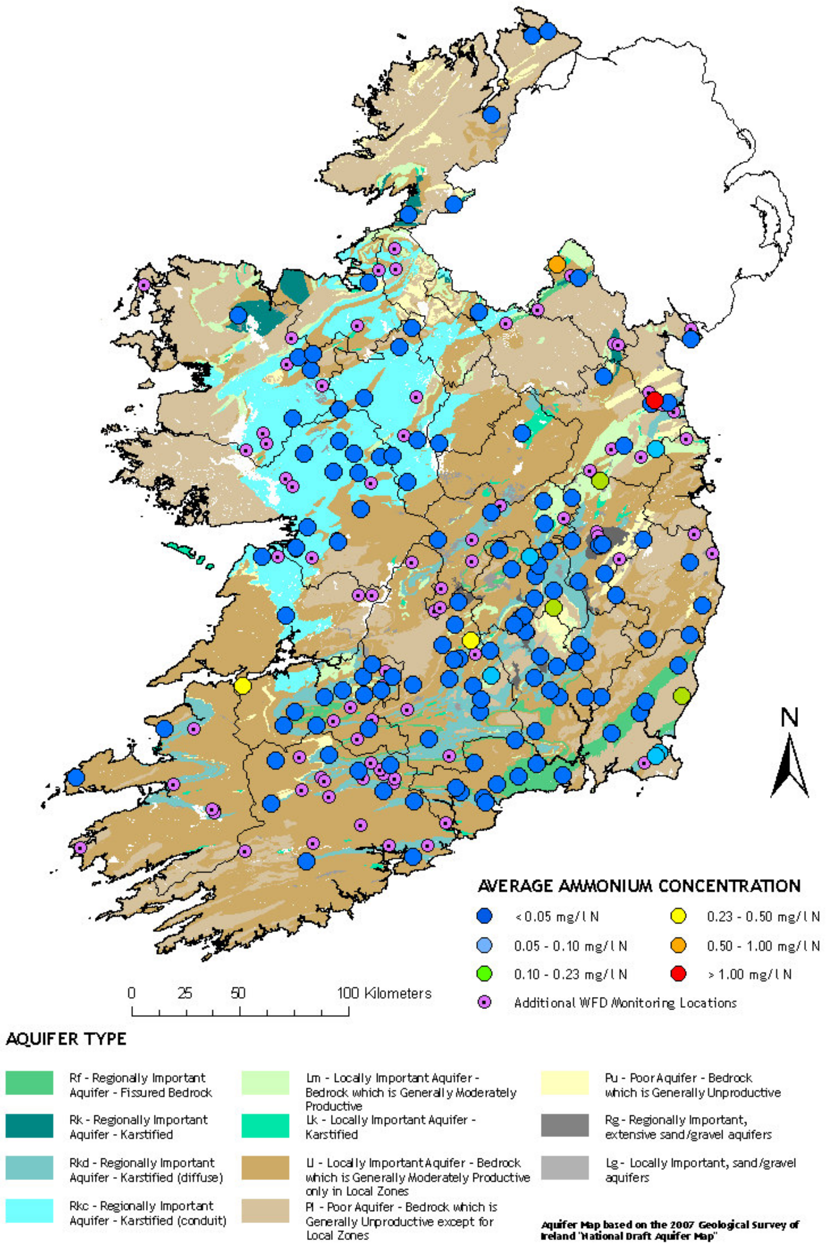


Figure 5.5. Comparison of the proportion of monitoring locations over the four recent reporting periods with mean ammonium concentrations in the ranges indicated.

Between 2004-2006, a total of 1,362 individual monitoring samples were analysed for ammonium at 137 monitoring stations. The mean concentration results are summarised in Figure 5.5 and the monitoring locations are shown in Map 5.3. The majority (90.5%) of the monitoring locations had mean concentrations less than 0.05 mg/l N, with concentrations greater than 0.23 mg/l N recorded at only 4 of the 137 monitoring locations. Two of the four monitoring locations also tested positive for faecal coliforms, possibly indicating that a nearby organic pollution source is getting into the water supply.

Only 15 samples had ammonium concentrations greater than the MAC value of 0.23 mg/l N. This suggests that that most of the monitoring locations in the network are not significantly impacted upon by any localised organic pollution sources. Although, on a national scale, there appears to be little impact from localised organic pollution on the groundwater quality of the monitoring locations in the network, other water supplies should still be properly installed in an appropriate location, e.g. not down gradient or too close to potential contamination sources, and they should be properly constructed with adequate grouting, so the risk of impact from surface contamination is reduced.



Map 5.3 Mean Ammonium Concentrations in Groundwater 2004-2006 (Source: GSI, EPA)

Figure 5.5 indicates that there have been no significant changes in ammonium concentrations at the monitoring locations between 1995 and 2006 and that the retention and attenuation capacities of the soil and subsoil overlying the aquifer reduce ammonium concentrations in groundwater. Therefore, those monitoring wells that are properly designed and constructed

and are not situated in high vulnerability areas, i.e. areas that have deep subsoils, are unlikely to have high ammonium concentrations.

Nitrate Relatively low concentrations of nitrate are found naturally in groundwater and concentrations higher than 10 mg/l as NO_3 (the NBL is 9.2 mg/l as NO_3) are usually indicative of anthropogenic organic or inorganic inputs. Organic sources can include waste disposal, e.g. animal waste spreading, or effluent from on-site wastewater treatment systems, whilst inorganic sources can include the spreading of artificial fertiliser. If a significant proportion of surface water flow is derived from groundwater, then increased nitrate concentrations in groundwater may contribute to eutrophication in surface waters.

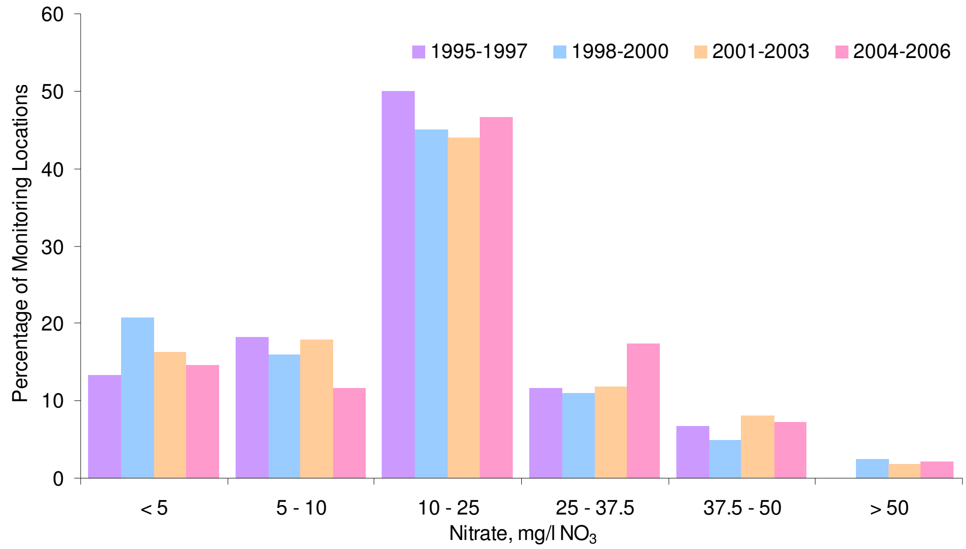


Figure 5. 6. Comparison of the proportion of monitoring locations over the four recent reporting periods with mean nitrate concentrations in the ranges indicated.

Under the Drinking Water Regulations, the MAC for nitrate is 50 mg/l as NO_3. In addition, a mean concentration of 37.5 mg/l NO_3 is an indication of appreciable contamination, which given the dynamic nature of groundwater in Ireland, would probably result in the Drinking Water MAC being exceeded at the monitoring point at some time during the sampling period.

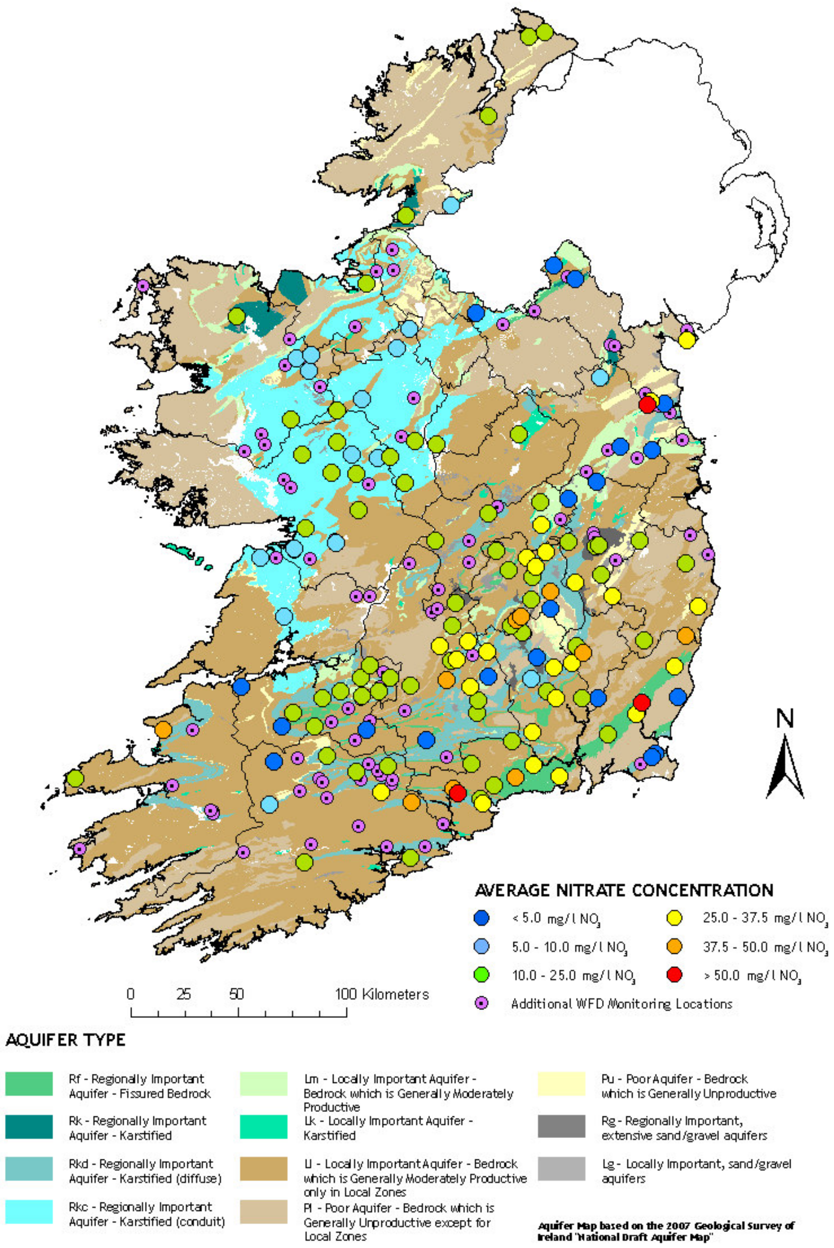
A total of 1,354 individual monitoring samples were analysed for nitrate at 137 monitoring locations between 2004-2006. The mean concentration results are summarised in Figure 5.6

and the monitoring locations are shown in Map 5.4. At 13 (9.5%) of the monitoring locations, the mean concentrations exceeded the threshold value of 37.5 mg/l NO_3, while at 3 of these locations, 50 mg/l NO_3 was exceeded.

Concentrations greater than 37.5 mg/l NO_3 were recorded in 139 individual samples, of which 35 exceeded the MAC of 50 mg/l NO_3.

Figure 5.6 indicates that there has been a slight increase in nitrate concentrations between 1995 and 2006. The slight decrease in the percentage of samples less than 10 mg/l NO_3 and the slight increase in the percentage of samples greater than 25mg/l NO_3, may be an indication of an overall increase in nitrate concentrations nationally, however the available data are not sufficient to make confident conclusions.

Generally, the south-east of the country has the greatest proportion of monitoring locations with elevated nitrate concentrations. Although elevated nitrate concentrations may be observed in monitoring points that are in close proximity to point source waste discharges, the intensive agricultural practices in the south-east, and low concentrations of ammonium at the same locations in this area suggests that diffuse, agricultural sources are the cause.



Map 5.4. Mean Nitrate Concentrations in Groundwater 2004-2006 (Source: GSI, EPA)

Phosphate Phosphate is a major source of concern for surface waters because small amounts may lead to eutrophication of lakes and rivers. Historically, phosphate was not considered to be a significant problem in groundwater because it is not very mobile in soils or sediments and should therefore be retained in the soil zone. However, in extremely vulnerable areas, where the soil and subsoil are shallow and where phosphate enters groundwater in significant quantities, groundwater may act as an additional nutrient enrichment pathway for receptors such as lakes, rivers and wetlands.

The MAC for phosphorus in drinking water is 5 mg/l as P_2O_5, equivalent to 2.2 mg/l P (S.I. No. 81 of 1988). This is well above natural concentrations (the NBL is 0.02 mg/l P) and an annual median phosphate concentration of 0.03 mg/l P, cited as a limit (to prevent eutrophication in surfaces waters) in the Phosphate Regulations (EPA, 2005). This may be taken as a threshold value for groundwater, where groundwater contributes a large proportion of the flow in receiving surface waters, e.g. in the Karstic Limestone aquifers in Galway, Mayo and Roscommon.

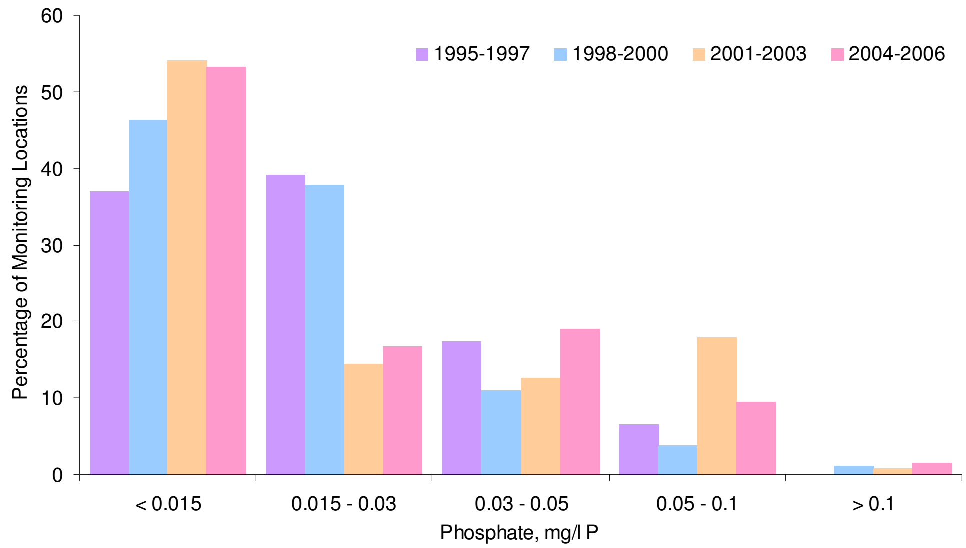
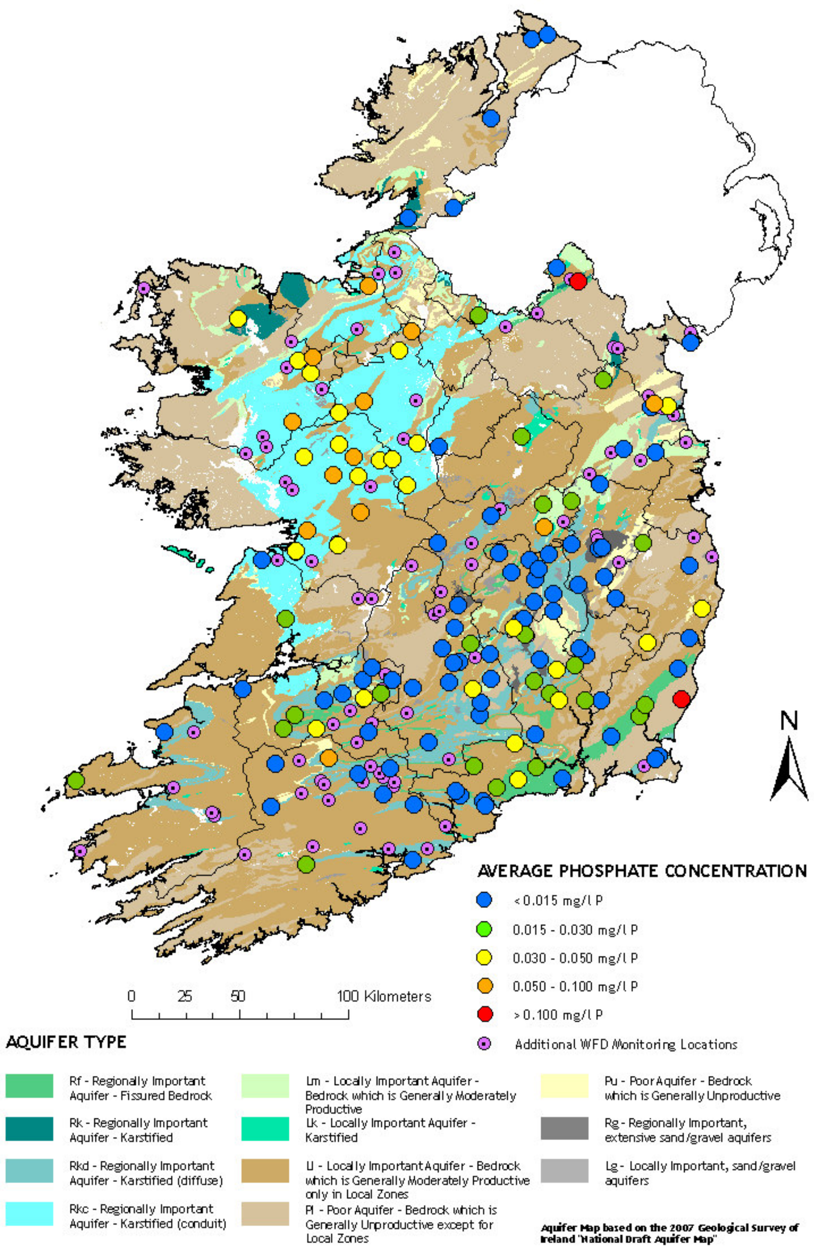


Figure 5.7 Comparison of the proportion of monitoring locations over the four recent reporting periods with mean phosphate concentrations in the ranges indicated.

Between 2004-2006, a total of 1,345 individual samples were analysed for phosphate at 137 monitoring locations. The mean concentration results are summarised in Figure 5.7 and the monitoring locations are shown in Map 5.5. Mean concentrations of phosphate exceeded 0.03 mg/l P at 41 monitoring locations, 15 of which exceeded 0.05 mg/l P.

Concentrations greater than 0.03 mg/l P were recorded in 318 samples; one of which exceeded the MAC of 2.2 mg/l P. This sample had a concentration of 3.34 mg/l P, and this concentration is not considered to be an outlier in the data because the mean concentration at that monitoring point was 2.95 mg/l P.

Figure 5.7 indicates that between 1995 and 2006, there has been a gradual increase in the percentage of locations with mean phosphate concentrations less than 0.015 mg/l P. However, there has been also been an increase in the percentage of stations with mean phosphate concentrations greater than 0.03 mg/l P.



Map 5.5 Mean Phosphate Concentrations in Groundwater 2004-2006 (Source: GSI, EPA)

In general phosphate concentrations in groundwater are not a cause of concern in relation to its use as a drinking water supply. However, there are areas of the country where groundwater contributes significantly to flows in rivers, e.g. 60 to 80 percent of the surface water flow comes from groundwater. If the phosphate concentrations in groundwater are approaching 0.03 mg/l P in these areas; then groundwater may be contributing to eutrophication in rivers and lakes.

Map 5.5 indicates that elevated phosphate concentrations have been measured in the west of Ireland, particularly at monitoring locations in the Karst Limestone (predominantly conduit flow). This reflects the vulnerable nature of these aquifers and the relative ease of transport of pollutants within the conduit systems, as these systems are much akin to rivers underground.

Microbiological Contamination Microbiological contamination is most likely to arise from the entry of faecal matter to waters. In practice, the presence of faecal coliform bacteria (e.g. Escherichia coli) in water samples is taken as an indicator of faecal contamination and thus of the potential presence of associated pathogenic micro-organisms, i.e. those organisms capable of causing disease (e.g. viruses and the protozoan cryptosporidium).

Sources of Escherichia coli (E. coli) and other faecal coliforms that are likely to contaminate groundwater include effluent from on-site wastewater treatment systems and agricultural organic wastes. The natural environment, particularly soils and subsoils, can be effective in removing bacteria and viruses by filtration and absorption and ingestion by worms and other soil organisms. However, not all areas are naturally well protected. Extremely vulnerable areas, including Karst aquifers, fractured aquifers and areas with exposed outcrop or shallow soils, allow the rapid movement of contaminants into groundwater with minimal attenuation. While the presence of glacial till subsoils and peat will, in many instances, retard the vertical migration of microbes; preferential secondary flow paths such as cracks in clay materials can allow the filtering effect of the subsoils to be reduced or bypassed.

From the perspective of human use and consumption of groundwater, the most important consideration is the absence of pathogens. Disinfection techniques, e.g. chlorination, are used to counteract this potential problem in public water treatment. However, the majority of private groundwater supplies do not undergo any treatment prior to use. The delineation of

source protection areas around water supplies provides an area in which protective measures can be applied. The source protection area is based on the premise that in some circumstances, bacteria and viruses can live longer than 50 days in groundwater and proper management of activities within this area should reduce the risk of bacteriological contamination of the water supply.

Between 2004-06, a total of 1,330 samples were analysed for faecal coliforms at 135 monitoring locations. If systems, such as chlorination, were in place to treat the abstracted water, then samples were taken prior to treatment being undertaken. Positive faecal coliform counts were detected in 338 (25.4%) samples, 143 (10.9%) of which exceeded 10/100 ml (Figure 5.8). Positive counts were detected at 79 (58.5%) monitoring locations (Map 5.6) on one or more occasions during the reporting period. A count of 10/100 ml is regarded as an indication of gross contamination. Faecal coliform counts in excess of 10/100 ml were recorded at 50 (37%) monitoring locations.

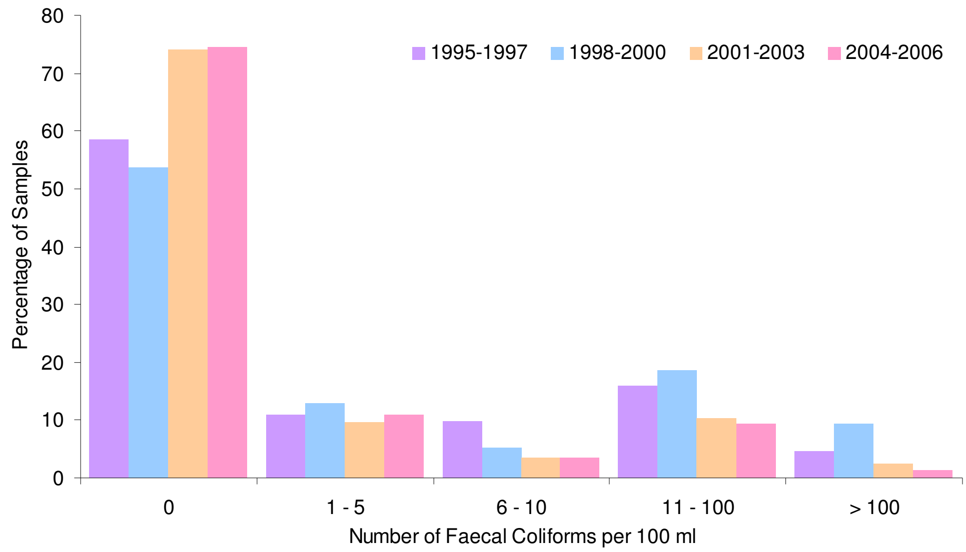
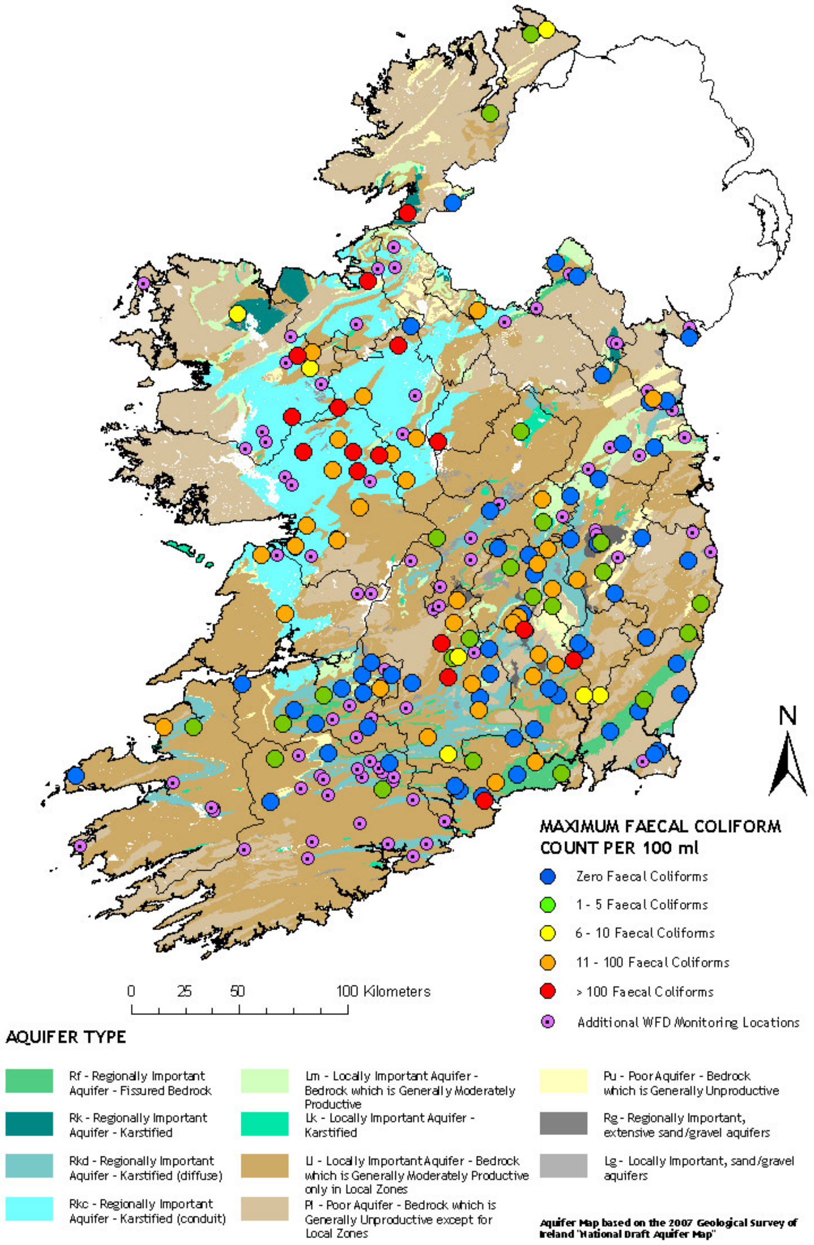


Figure 5.8. Comparison of the proportion of samples over the four recent reporting periods with the number of faecal coliforms detected in the ranges indicated.

Figure 5.8 indicates that there has been a gradual increase in the number of samples with zero faecal coliforms between 1995 and 2006, and there has been a slight decrease in the percentage of samples in each of the other categories during the same period.



Map 5.6 Faecal Coliform Detections in Groundwater 2004-2006 (Source: GSI, EPA)

Map 5.6 indicates that the groundwater monitoring locations in Karst limestone areas show the greatest degree of microbiological pollution. The highest faecal coliform counts were recorded in groundwater springs. This reflects the vulnerable nature of the more dynamic flow systems to pollution and the lack of attenuation capacity in extremely vulnerable areas with shallow soil or subsoil. Many private supplies are untreated and the sources of contamination of the groundwater quality are unknown, or are beyond the control of the owner of the supply. Therefore, general improvements in well design, knowledge of source

protection and good land use practice are essential if the risks to these supplies are to be reduced and improvements in water quality are to be seen.

Cryptosporidium is a microscopic protozoan parasite that can be present in faecal material. The first recorded outbreak of cryptosporidium in Ireland associated with a public water supply occurred in Mullingar, in April 2002 (EPA, 2008b) and there have been a number of cryptosporidium outbreaks recorded since this date. The cyst is resistant to conventional water supply disinfection, e.g. chlorination. Elevated levels of turbidity have been shown to be associated with outbreaks of cryptosporidium (EPA, 2008b) and this should be monitored as a surrogate for cryptosporidium. Whilst improvements in drinking water treatment works design (to reduce turbidity), and the introduction of ultra-violet treatment systems, reduces the risk to human health from cryptosporidium in drinking water, better understanding of the physical characteristics of the landscape in the areas surrounding the water supply, in particular the groundwater vulnerability and knowledge of where the source water for the water supply is coming from, would reduce the risk of contamination in the first instance, as measures could be taken to reduce the anthropogenic pressures on these areas.

Any indication of faecal contamination of drinking water must be regarded as a matter of serious concern and the circumstances promptly investigated. This matter has been addressed in detail in the annual reports on drinking water quality published by the EPA (e.g., EPA, 2008a).

GROUNDWATER CLASSIFICATION AND MEASURES

Whilst, point source pressures may have an adverse impact on groundwater, generally the point source activity only impacts on a small area. Furthermore, the activities associated with the point source pressure are often regulated. Therefore, adherence to, and enforcement of the regulations relating to point discharges to groundwater should minimise the impacts from these sources. Where there is evidence that a point source activity is impacting on a widespread area, i.e. a significant proportion of a groundwater body, or is impacting on surface water and/or ecological receptors (using groundwater as a pathway), then measures may have to be introduced, or there may have to be stricter enforcement of existing regulations, to prevent further anthropogenic impacts on groundwater.

Improving public awareness of the potential impacts of point source activities at the local scale, through the development of 'good practice' guidance, may help reduce the anthropogenic impacts on groundwater from pressures that are not regulated activities, e.g. the correct location for an on-site wastewater treatment system. The most significant pressures on groundwater are from diffuse sources, whether that is from agricultural activities, or the usage of potentially dangerous substances, e.g. agrochemicals.

The WFD groundwater classification will largely be determined by the impact of groundwater on associated surface water and ecological receptors, or by the deterioration of groundwater quality abstracted for drinking water.

For example, mean nitrate concentrations above 37.5 mg/l NO_3 in groundwater are likely to result in a breach of the Nitrate MAC at drinking water sources. Ultimately measures may be required in some areas to reduce the nitrate concentration in groundwater. Therefore, improved knowledge of the groundwater system and the source areas contributing to a water supply are paramount if effective and fair measures are to be introduced.

Phosphate concentrations in surface waters are a major concern. Therefore, in areas where groundwater provides a significant contribution to river flow, it could also potentially provide a significant contribution of phosphate to the river. In the west of Ireland, groundwater contributions to river flow, from the Karst Limestone aquifers, are significant and therefore the associated nutrient loading from groundwater to the rivers and lakes could also be significant. Integrated measures may have to be introduced to cover both direct surface water inputs, e.g. from treatment works, and diffuse groundwater inputs.

The risk of potential impact from bacteriological contamination on the groundwater spring sources in the Karst aquifers is also fairly high. Again, improved knowledge of the groundwater system and the source areas contributing to a water supply are critical in these aquifers.

FUTURE DEVELOPMENTS

The WFD has provided a time scale of 2015 for each Member State to reduce the anthropogenic impacts on its water bodies and restore them to 'good' status. Each Member State must determine what is required to achieve 'good' groundwater status, but the

approach is largely two fold, with classification providing the basis to drive measures in areas that are currently failing to achieve 'good' status and 'prevent or limit' regulations, e.g. licensing activities, employed to prevent further deterioration. The approach will be iterative, with ongoing assessment helping to determine the exact nature of the problem and to examine the impacts of measures.

The delineation of areas contributing to a groundwater abstraction, in particular Source Protection Zones for water supply abstractions is critical to the success of any measures taken to reduce the anthropogenic impacts on the water supply. The delineation of Source Protection Zones has been undertaken by the Geological Survey of Ireland at a number of water supplies in Ireland and it is envisaged that more will be delineated in the future by the Geological Survey of Ireland, and others, to meet the requirements of the WFD. Once a Source Protection Zone has been delineated, it provides an area in which measures can be applied. These measures will largely focus on areas that are more vulnerable to anthropogenic contaminants entering the aquifer, e.g. in areas where there are shallow soils and subsoils.

CONCLUSIONS

Groundwater is an important natural resource; both in terms of yield and water quality. Therefore, to ensure that long-term sustainable groundwater resources are achieved, groundwater resource management is required, through an assessment of anthropogenic pressures and the physical characteristics of the subsurface deposits, i.e. soil, subsoil and aquifer type.

Natural variations in groundwater hydrochemistry should be considered when assessing water quality data from groundwater monitoring programmes, as elevated concentrations for certain parameters might be influenced by the aquifer lithology. Although natural variations in nitrate and phosphate concentrations may influence water quality assessments on a local scale, the elevated concentrations of nitrate and phosphate measured in Irish groundwater are largely anthropogenic.

There have been slight increases in nitrate and phosphate concentrations between 1995 and 2006, with elevated nitrate concentrations observed in the east and south-east of the country and elevated phosphate concentrations in the west. The intensive agricultural practices in the

south-east suggests that diffuse, agricultural sources are the cause of the elevated nitrate concentrations and the vulnerable nature of the Karst Limestone aquifers in the west may explain the elevated phosphate concentrations in groundwater, and groundwater may be contributing to eutrophication in rivers and lakes in these areas.

Microbiological problems are also observed in the more vulnerable aquifers (particularly at spring monitoring locations) because they have little natural protection from organic inputs, e.g. animal waste spreading. However, if abstraction wells are properly designed and installed, and are located in areas where the aquifer vulnerability is lower, the impacts of organic inputs should be minimal.

There is a need for improved protection of groundwater, especially in the context of achieving the Water Framework Directive objective of 'good status' for all waters by 2015. To meet the objectives of the WFD, an improved understanding of the interactions between groundwater and surface water receptors is required because this understanding is fundamental if further deterioration in water quality is to be prevented and sustainable water resources are going to be achieved.

This understanding may help improve management of groundwater resources, and ultimately maintain the quality and yield of drinking water sources, and ensure that groundwater is not having a detrimental impact on surface water and ecological receptors.

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