



Groundwater is an important natural resource in terms of both water supply and water quality. Groundwater provides approximately 26 per cent of the total drinking water supplied in Ireland. There were slight increases in nitrate and phosphate concentrations in groundwater 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. Microbiological problems are also observed in the more vulnerable aquifers (particularly at springs) because they have little natural protection from the pollutants in organic wastes (which may contain faecal bacteria), such as septic tank effluent and farm manures and slurries.

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. Proper management of groundwater resources is required to maintain both the quality and the yield of drinking water sources, and to ensure that groundwater is not having a detrimental impact on surface water and ecological receptors.

GROUNDWATER



Introduction

Groundwater is a valuable natural resource in Ireland, used in food and industrial processing, as well as being an important source of drinking water. Groundwater flows through and is stored in the pore spaces and fractures in bedrock geological deposits. 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.

The interaction between groundwater and surface water is complex. Groundwater chemical composition is often uncertain and its contributions to surface water flow vary; often the contribution is less than 10 per cent in the low yielding 'poorly productive' aquifers (Figure 6.1), but it may be up to 80 or 90 per cent in the more productive aquifers (Figure 6.2), e.g. karstified limestone or sand and gravel aquifers.

In contrast with most other EU countries, the bedrock aquifers in Ireland have fissure permeability only. Therefore, water flow is predominantly through fissures or fractures 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 per cent of the country are the only aquifers with intergranular permeability. Aquifers are protected by the overlying soil and subsoil, where some attenuation of contaminants may occur; therefore variation in soil and subsoil type, and thickness, is important in characterising the vulnerability of aquifers to contamination.

Figure 6.1 Groundwater Contributions to Wells and Surface Waters are Mainly Limited to Flows at Shallow Depths in Poorly Productive Aquifers (Source: www.wfdvisual.com)

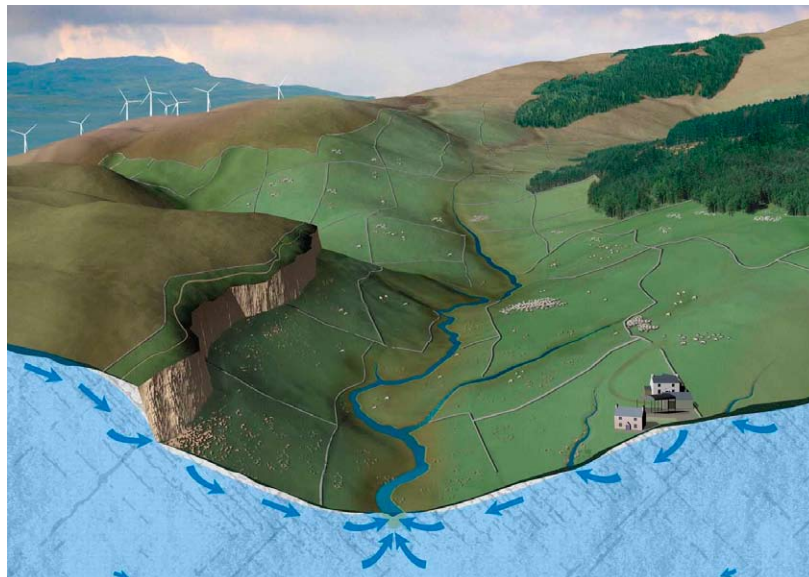
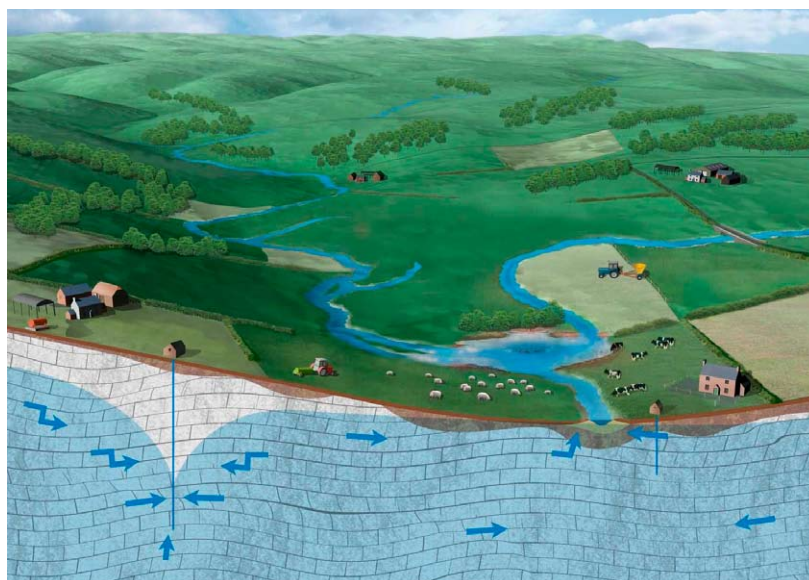


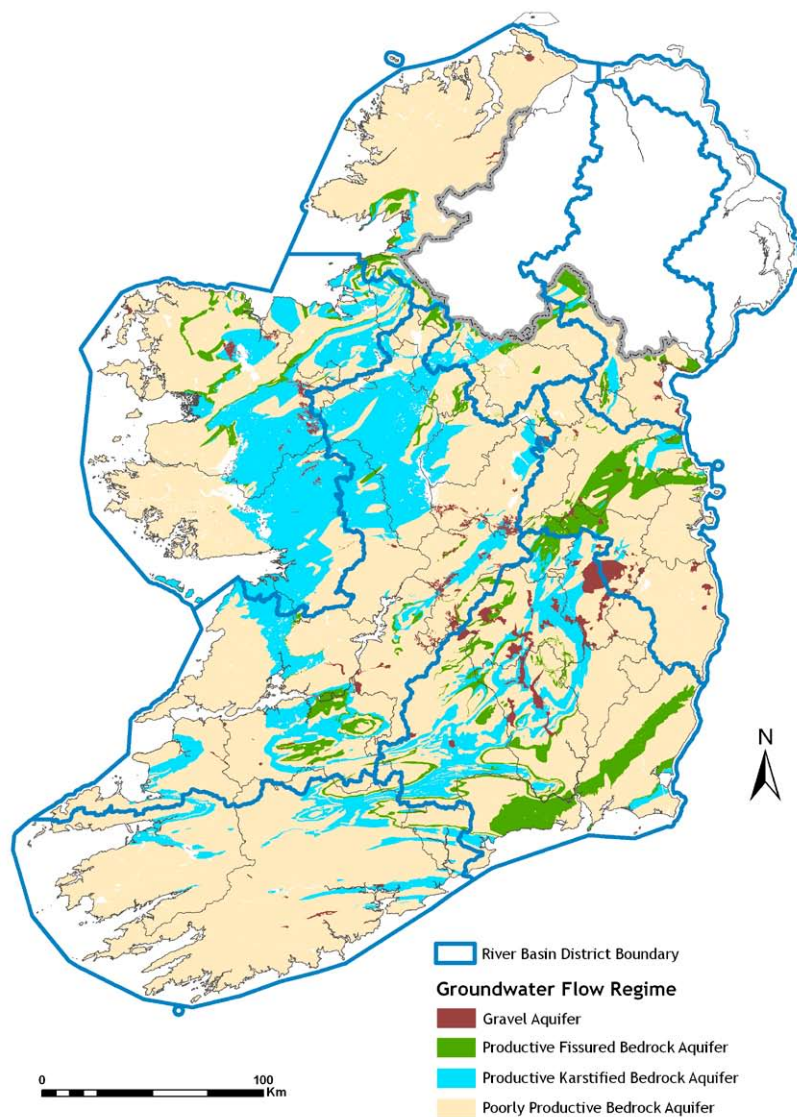
Figure 6.2 Groundwater Provides a Significant Contribution to Wells and Surface Waters in Productive Aquifers (Source: www.wfdvisual.com)



Map 6.1 shows a simplified groundwater flow regime map for Ireland. A large proportion of the productive aquifers in Ireland are karstified limestone. 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).

Map 6.1 Simplified Groundwater Flow Regime Map of Ireland
(Source: GSI)



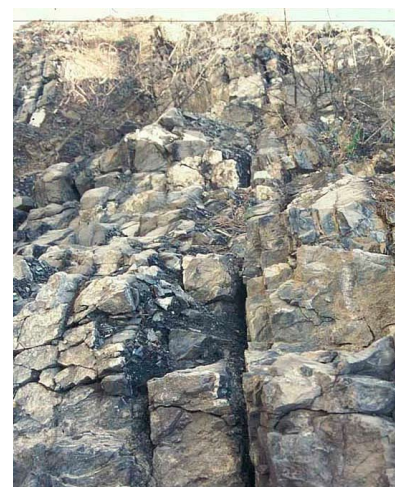
Groundwater Sources of Drinking Water

Approximately 17 per cent of the total public drinking water supply in Ireland is provided by groundwater or spring sources (EPA, 2008a). If private supplies are included, then groundwater and springs account for approximately 26 per cent of the total drinking water supplied in Ireland. In certain counties it provides a significantly higher percentage,

e.g. approximately 75 per cent in Co. Roscommon (EPA, 2007). Although treated public water supplies and public group water schemes account for approximately 85 per cent 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 they often have inadequate treatment or, in many cases, no treatment at all. Therefore, to protect private supplies and reduce the risk of pollution of public supplies, there needs to be adequate protection of groundwater as a resource.

Figure 6.3 Fissures in a Limestone Bedrock Aquifer in Co. Kilkenny



Groundwater and the WFD

As indicated in Chapter 5, the Water Framework Directive (WFD) establishes a framework for the protection of all waters (including inland surface waters, transitional waters, coastal waters and groundwater) and is aimed at preventing further deterioration in water quality and achieving sustainable water resources. It promotes an integrated management strategy for the protection of all waters, which requires the development of improved understanding of the interactions between waters.

The WFD requires that each member state delineate water-body units to represent variation in physical characteristics and anthropogenic pressures. In Ireland, groundwater body delineation and risk assessments

for different anthropogenic pressures were completed in 2005. Subsequently, monitoring networks were developed to validate the risk assessments, to identify trends in water quality and quantity, and to provide the basis for water-body classification. Once the initial groundwater body classification has been completed, measures may be introduced to improve the status of groundwater bodies classified as being at 'poor' status. Measures may also be introduced to prevent any future deterioration in groundwater status and to 'prevent or limit' the input of pollutants to groundwater. Thereafter, monitoring networks will also be used to determine the effectiveness of these measures.

The assessment criteria used to determine 'good' status are to be defined by each member state, but they should reflect the underlying ethos of the WFD. For groundwater, this includes assessments of water resource sustainability, groundwater quality at existing drinking water abstractions and the impacts of groundwater on associated surface water and ecological receptors.

WFD Risk Characterisation

The WFD Article 5 risk assessment (WFD Groundwater Working Group, 2004) indicated that approximately 61 per cent of the groundwater bodies in Ireland are at risk from anthropogenic pressures. The groundwater resource risk assessment indicated that only a small number of groundwater bodies are at risk from groundwater abstraction pressures. The 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 unlikely to exert a significant influence on an entire groundwater body, as groundwater bodies are relatively large units (generally over 50 km²).

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

Groundwater Monitoring

Groundwater monitoring networks have been developed to improve knowledge of, and the links between, groundwater and the ecological health of associated receptors (e.g. rivers and wetlands). Monitoring data will be used to help assess the general status of groundwater quality and groundwater resources (levels and flows) in Ireland. This information will be used to establish measures that will help protect groundwater used for public and private drinking water supplies. The measures are also designed to help protect surface water and ecological receptors (e.g. rivers and wetlands) 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 per cent of the bedrock aquifers in Ireland are generally unable to yield significant quantities of groundwater for abstraction and groundwater flow paths are relatively short. A dispersed network of monitoring in these 'poorly productive' aquifers would not be beneficial. Therefore monitoring networks in these aquifers have been developed to focus on groundwater bodies where there are sensitive receptors (e.g. rivers and wetlands), considered to be 'at risk' from abstraction. Monitoring in the poorly productive aquifers will focus on large abstractions along major fault zones and clusters of monitoring points in a small number of bedrock aquifers (e.g. granites) that are representative of different poorly productive aquifers in Ireland.

Figure 6.4 Drilling in a Poorly Productive Granite Aquifer, Co. Galway



Monitoring data from selected compliance monitoring, e.g. from Integrated Pollution Prevention and Control (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, for example 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.

Appraisal of Existing Groundwater Data

Historically, the EPA has monitored groundwater quality and groundwater levels 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, which 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 report 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 used. Data are presented for the period 2004–2006 and, for comparison, historical data from 1995–2003 are presented, again using only 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 its pilot groundwater risk assessment in 2004–2005. The data are presented for parameters that are indicators of anthropogenic pollution (ammonium, nitrate, phosphate and faecal coliforms) and comparison is made with the appropriate threshold values, standards and principles that will be used for WFD classification for these parameters; for example, 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 fewer than four samples were taken. This acknowledges the fact that the presence of a single faecal coliform in a drinking water supply is a breach of the Drinking Water Regulations (SI 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

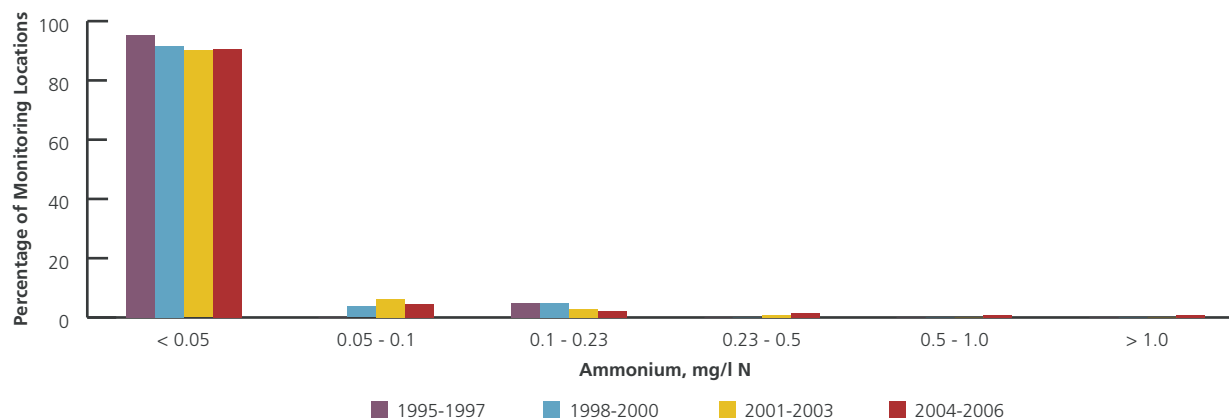
Microbiological reduction of nitrogen-containing compounds generally results in very low background concentrations of ammonium in natural waters. Ammonium has a low mobility in soil and subsoil. Its presence in groundwater much above 0.15 mg/l N is usually indicative of a

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). In certain areas, high ammonium concentrations may be encountered naturally, e.g. in peat land areas. Under the Drinking Water Regulations, the maximum allowed concentration (MAC) of ammonium is 0.23 mg/l as N.

Between 2004 and 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 6.5 and the monitoring locations are shown in Map 6.2. 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 four of the 137 monitoring locations. Two of the four monitoring locations also tested positive for faecal coliforms, possibly indicating that nearby organic pollution is getting into the groundwater.

Only 15 samples had ammonium concentrations greater than the MAC value of 0.23 mg/l N. This suggests that most of the monitoring locations in the network are not significantly impacted upon by any localised organic pollution sources. While, on a national scale, there appears to be little impact from localised organic pollution on the water quality of the monitoring locations in the network. Nevertheless, new water supplies should be properly installed in an appropriate location. They should not be 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.

Figure 6.5 Ammonium Concentrations in Groundwater



Map 6.2 Mean Ammonium Concentrations in Groundwater 2004–2006 (Source: GSI, EPA)

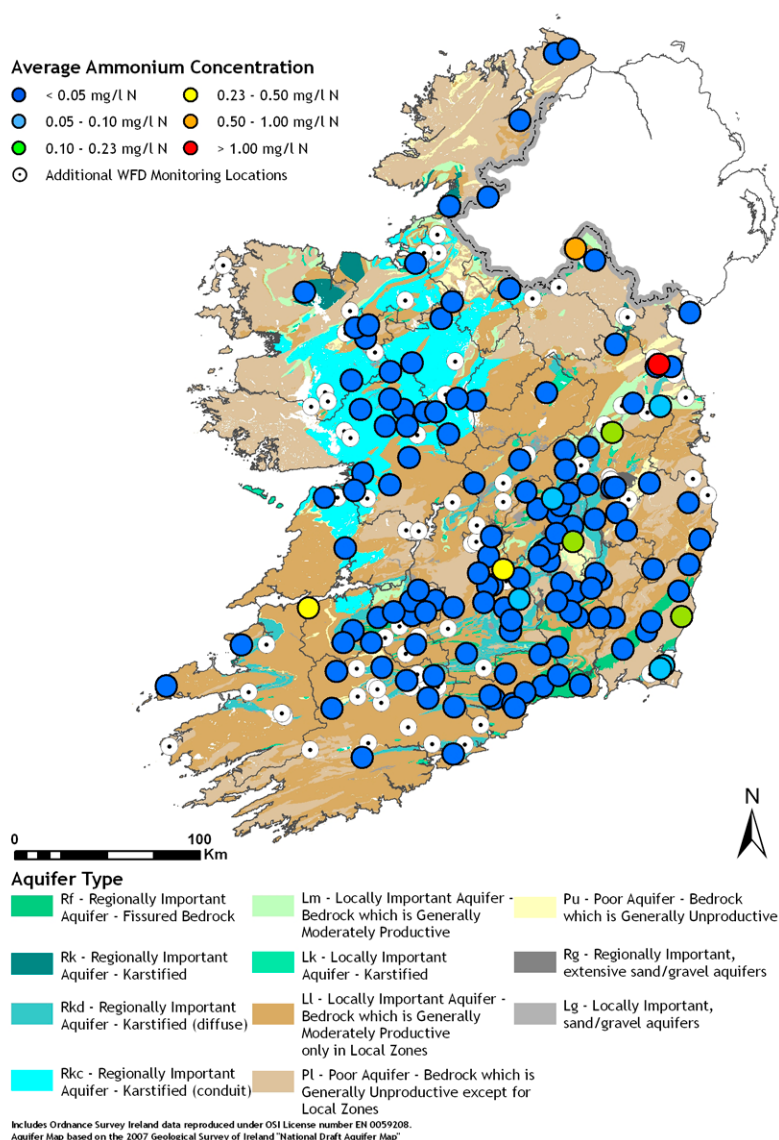
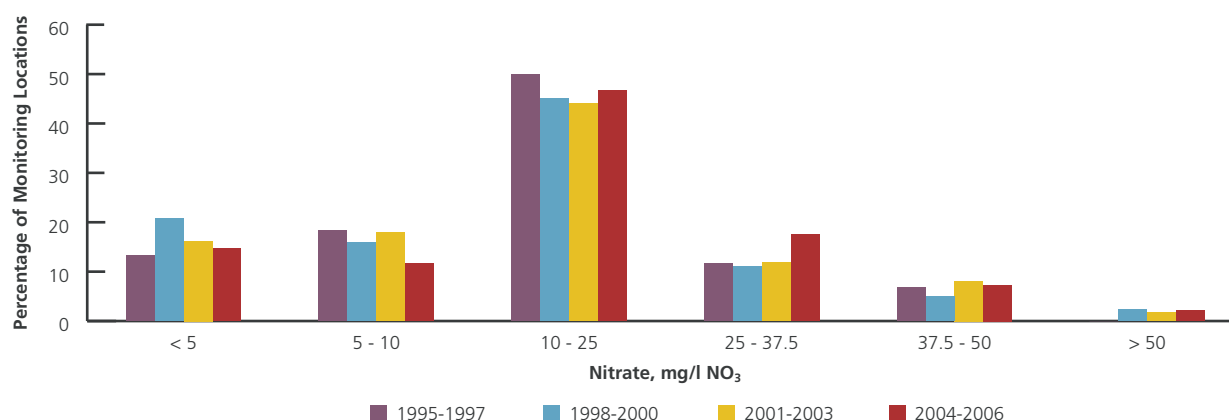


Figure 6.5 indicates that there have been no significant changes in ammonium concentrations at the monitoring locations between 1995 and 2006 and that the retention and attenuation capacities of the soil and subsoil overlying the aquifer reduce ammonium concentrations in groundwater. Therefore, monitoring wells that are properly designed and constructed and are situated in low- or moderate-vulnerability areas, i.e. areas that have deep soils and subsoils, are unlikely to have high ammonium concentrations.

Nitrate

Relatively low concentrations of nitrate are found naturally in groundwater. Higher nitrate concentrations 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, while 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 6.6 Nitrate Concentrations in Groundwater



Under the Drinking Water Regulations, the MAC for nitrate is 50 mg/l as NO₃. In addition, a mean concentration of 37.5 mg/l NO₃ 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 and 2006. The mean concentration results are summarised in Figure 6.6 and the monitoring locations are shown in Map 6.3. At 13 (9.5%) of the monitoring locations the mean concentrations exceeded the threshold value of 37.5 mg/l NO₃, while at three of these locations the MAC of 50 mg/l NO₃ was exceeded.

Concentrations greater than 37.5 mg/l NO₃ were recorded in 139 individual samples, of which 35 exceeded the MAC of 50 mg/l NO₃.

The slight decrease in the percentage of samples less than 10 mg/l NO₃ and the slight increase in the percentage of samples greater than 25 mg/l NO₃ may be an indication of an overall

increase in nitrate concentrations nationally, but the available data are not sufficient for confident conclusions to be drawn.

Generally, the south-east of the country has the greatest proportion of monitoring locations with elevated nitrate concentrations. The low concentrations of ammonium at these locations suggest that point sources of pollution are not having a significant impact on groundwater quality. This coupled with the intensive agricultural practices in the area suggests that diffuse agricultural sources are the main cause of the elevated nitrate concentration.

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, it 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 P₂O₅, equivalent to 2.2 mg/l P (SI No. 81 of 1988). This is well above natural levels and an annual median phosphate concentration of 0.03 mg/l P is cited as a limit (to prevent eutrophication in surface waters) in the Phosphate Regulations (EPA, 2005). This may be taken as a threshold value for groundwater that contributes a large proportion of the flow in receiving surface waters, e.g. in the Karstic limestone aquifers in Galway, Mayo and Roscommon.

Between 2004 and 2006, a total of 1,345 individual samples were analysed for phosphate at 137 monitoring locations. The mean concentration results are summarised in Figure 6.7 and the monitoring locations are shown in Map 6.4. Mean concentrations of phosphate exceeded 0.03 mg/l P at 41 (29.9%) monitoring locations, 15 (10.9%) 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 an average concentration of 3.34 mg/l P.

Map 6.3 Mean Nitrate Concentrations in Groundwater 2004–2006
(Source: GSI, EPA)

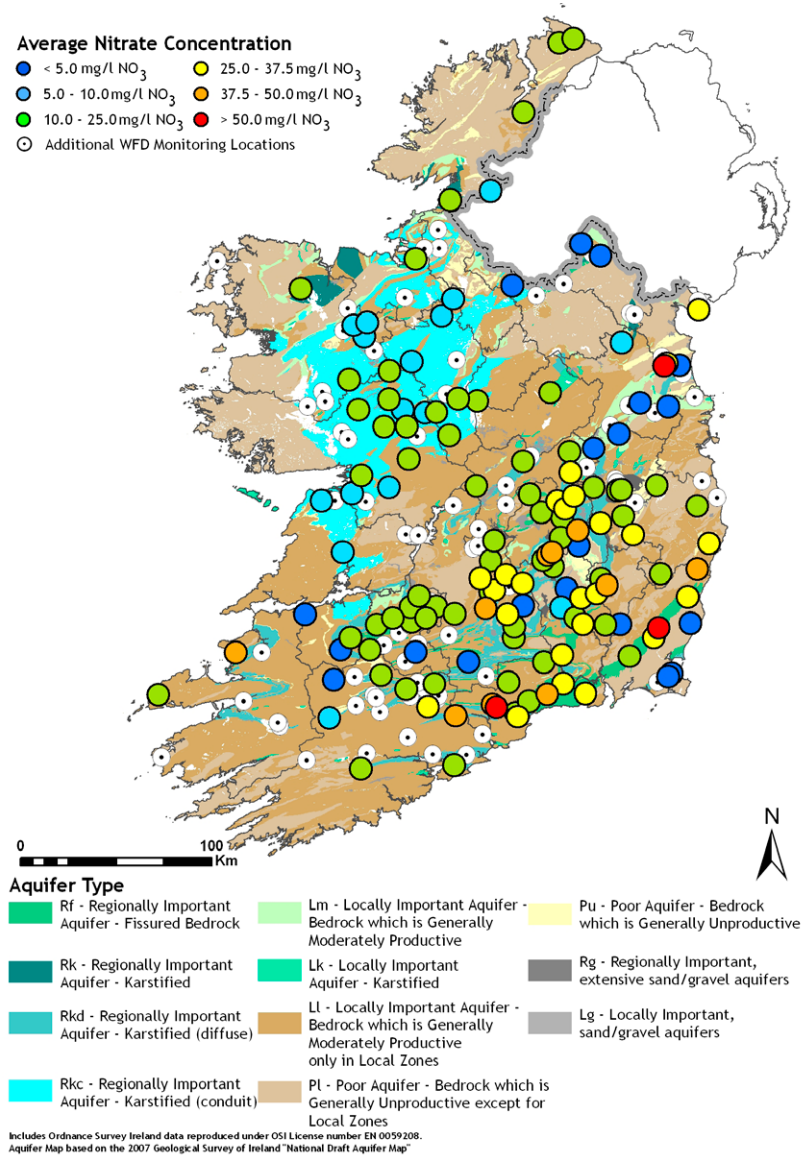


Figure 6.7 indicates that between 1995 and 2006 there was a gradual increase in the percentage of locations with mean phosphate concentrations less than 0.015 mg/l P. However, there was also an increase in the percentage of stations with mean phosphate concentrations greater than 0.03 mg/l P.

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 per cent of the surface water flow comes from groundwater. If the phosphate concentrations in groundwater are approaching 0.03 mg/l P in these areas, groundwater may be contributing to eutrophication in rivers and lakes.

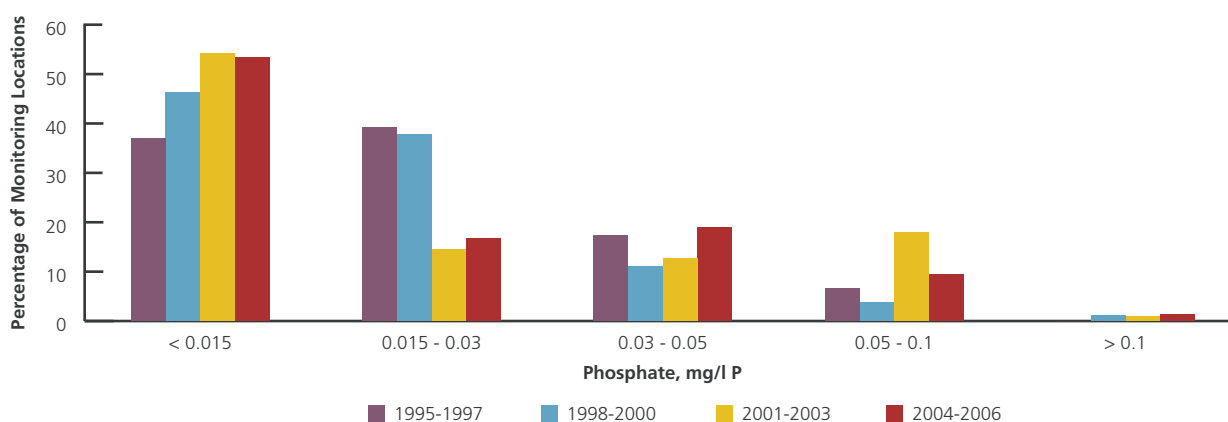
Map 6.4 indicates that elevated phosphate concentrations have been measured in the west of Ireland, particularly at monitoring locations in the Karst limestone (predominantly conduit flow). This reflects the vulnerable nature of these aquifers and the relative ease of transport of pollutants within the conduit systems, as these behave like underground rivers.

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 microorganisms, i.e. organisms capable of causing disease (e.g. viruses and the protozoan cryptosporidium).

Sources of *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.

Figure 6.7 Phosphate Concentrations in Groundwater



From the perspective of human use and consumption of groundwater, the most important consideration is the absence of pathogens. Disinfection techniques, e.g. filtration, chlorination and UV treatment, 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 are viable for greater than 50 days in groundwater and proper management of activities within this area should reduce the risk of microbiological contamination of the water supply.

Between 2004 and 2006, a total of 1,330 samples were analysed for faecal coliforms at 135 monitoring locations. Positive faecal coliform counts were detected in 338 (25.4%) samples, 143 (10.9%) of which exceeded 10/100 ml (Figure 6.8). Positive counts were detected at 79 (58.5%) monitoring locations (Map 6.5) on one or more occasions during the reporting period. A count

Map 6.4 Mean Phosphate Concentrations in Groundwater 2004–2006 (Source: GSI, EPA)

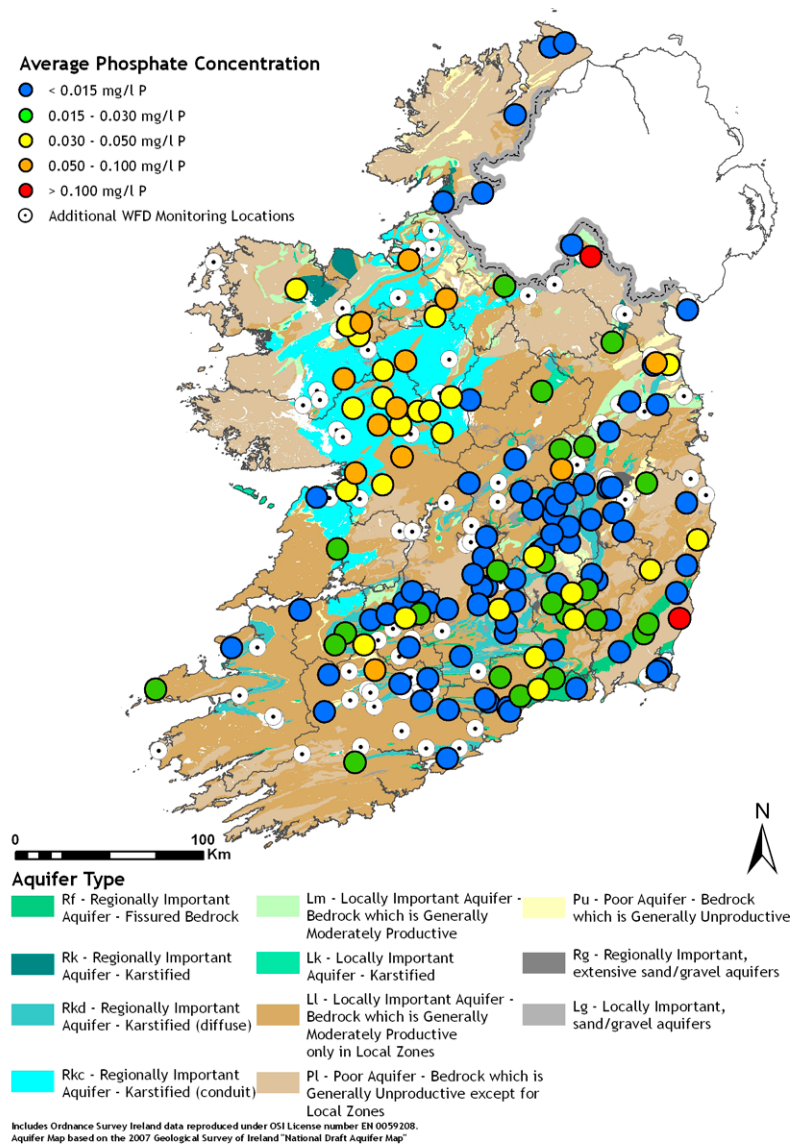
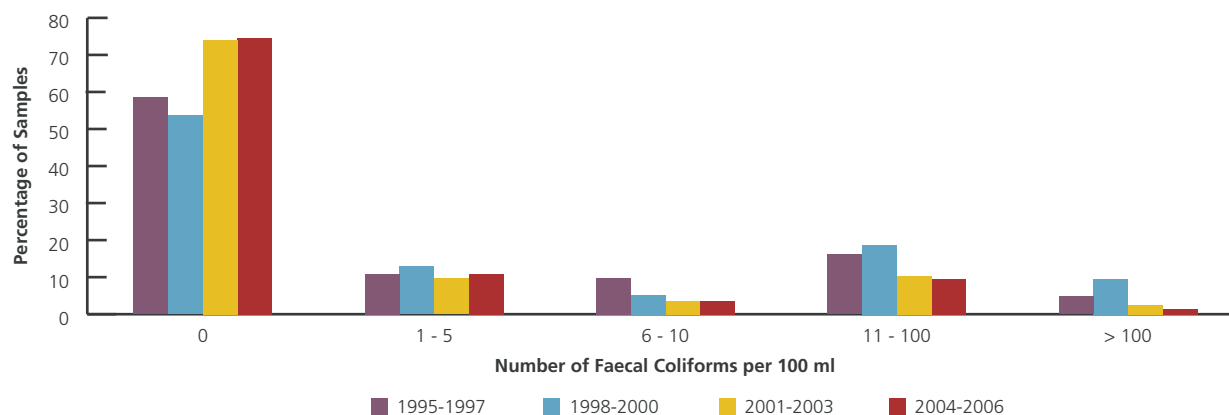


Figure 6.8 Faecal Coliforms in Groundwater

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 6.8 indicates that there has been an 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 6.5 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 factors influencing the water 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 April 2002 (EPA, 2008b); there have been a number of cryptosporidium outbreaks since this date. The cyst is resistant to conventional water supply disinfection, e.g. chlorination. Outbreaks of cryptosporidium (EPA, 2008b) have been shown to be associated with elevated levels of turbidity. Improvements in drinking water treatment works design (to reduce turbidity) and the introduction of ultraviolet treatment systems reduce the risk to human health from cryptosporidium in drinking water. An overall better understanding of the physical characteristics of the land 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.

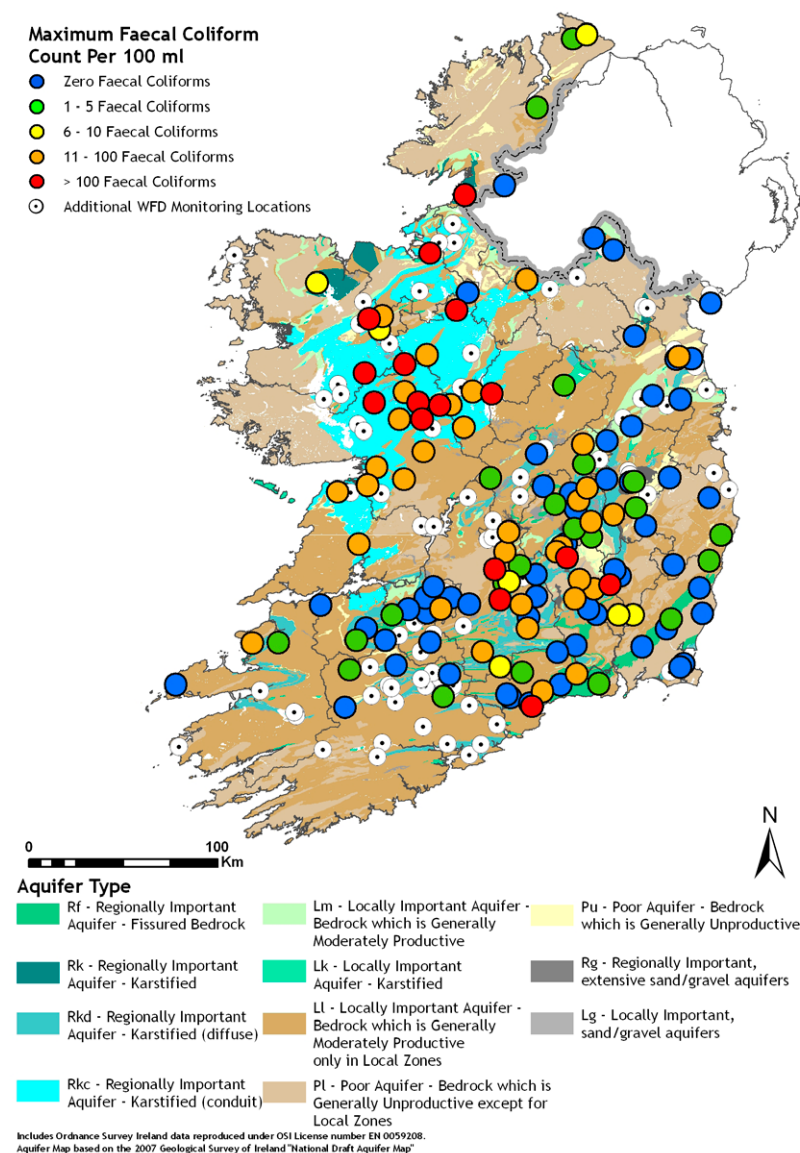
Any indication of faecal contamination of drinking water must be regarded as a matter of serious concern and the circumstances promptly investigated. This matter has been addressed in detail in the annual reports on drinking water quality published by the EPA (e.g. EPA, 2008a).

Groundwater Levels

Historically, both the EPA and the Geological Survey of Ireland (GSI) have monitored groundwater levels at a number of monitoring locations nationally. The WFD groundwater-level network has been developed to take account of short- and long-term variations in groundwater recharge and the impacts of abstractions and discharges on groundwater levels.

Generally, widespread abstraction pressures on groundwater are not significant in Ireland and the WFD groundwater level network will be used to observe natural fluctuations (e.g. Figure 6.9) in groundwater level within productive aquifers, ultimately providing information that will help improve the conceptual understanding of the groundwater system.

Map 6.5 Faecal Coliform Detections in Groundwater 2004–2006
(Source: GSI, EPA)



Groundwater Classification and Measures

While anthropogenic point-source pressures may have an impact on groundwater, the activity often only impacts on a small area and the activities associated with the point-source pressure are often regulated. Therefore, adherence to, and enforcement of, the regulations relating to groundwater should minimise the impacts of these point-source activities. 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), measures may have to be introduced. Alternatively there may have to be stricter enforcement of existing regulations, to prevent further anthropogenic pressures from impacting 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 to reduce the impact of anthropogenic pressures on groundwater that are not regulated activities, for example the correct location for an on-site wastewater treatment system or an integrated constructed wetland. The most significant pressures on groundwater are from diffuse sources, whether 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 used for drinking water.

However, where abstraction pressures are impacting on groundwater levels (e.g. Figure 6.10), the monitoring network will be used to support groundwater classification and provide evidence that measures, such as reducing groundwater abstraction, are having a beneficial impact on the groundwater level.

In addition to monitoring groundwater levels, the EPA will monitor groundwater spring flows at a number of locations nationally. This will improve the conceptual understanding of groundwater movement within an aquifer and will assist in the calculation of groundwater contaminant loadings to associated surface water and ecological receptors.

Figure 6.9 Seasonal Groundwater-Level Fluctuations at a Monitoring Location in Co. Mayo

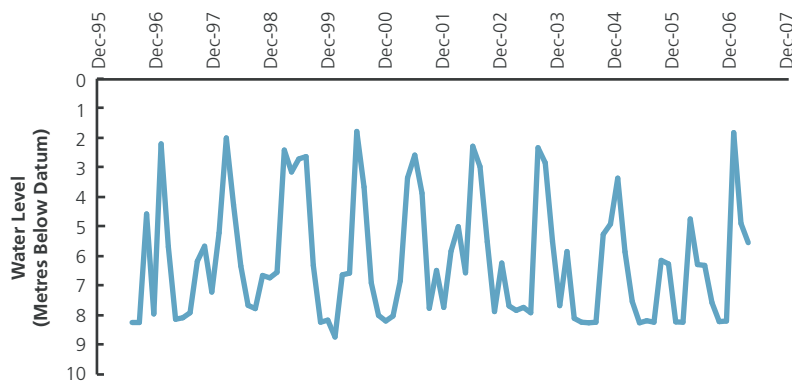
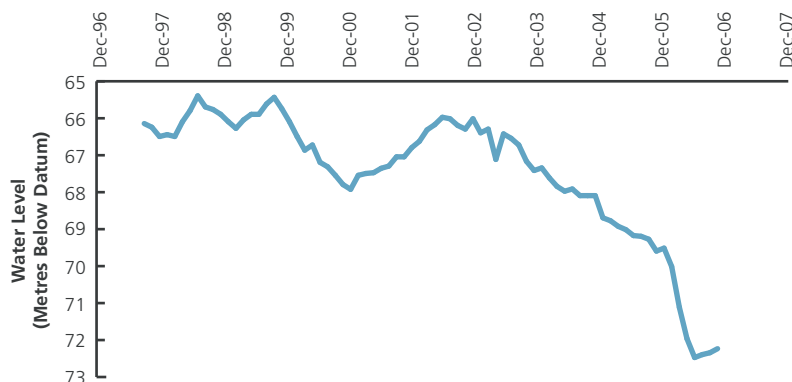


Figure 6.10 Declining Groundwater Levels at a Monitoring Location in Co. Monaghan



For example, mean nitrate concentrations above 37.5 mg/l NO_3 (8.5 mg/l N) 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. 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 microbiological 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 is 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. Classification will be used to drive measures in areas that are currently failing to achieve 'good' status and 'prevent or limit' regulations, e.g. licensing activities, will be used to prevent further deterioration. The approach will be iterative, with ongoing assessment used 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 pressures on the water supply. The delineation of Source Protection Zones has been undertaken by the GSI at a number of water supplies in Ireland and it is envisaged that more will be delineated in the future by the GSI 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 contaminants entering the aquifer, e.g. in areas where there are shallow soils and subsoils.

Groundwater Directive

The EU Directive on 'the Protection of Groundwater Against Pollution and Deterioration' (Groundwater Daughter Directive, 2006/118/EC) provides the detail on the means by which the WFD requirements to prevent and control groundwater pollution are met. In particular, it sets out criteria and procedures for assessing groundwater chemical status and requires the 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 of the need to protect groundwater not only 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.

Conclusions

Groundwater is an important natural resource in terms of both yield and water quality. Therefore, to ensure that long-term sustainable groundwater resources are achieved, 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. Proper management of groundwater resources is needed in order to maintain the quality and yield of

drinking water sources, and to ensure that groundwater is not having a detrimental impact on surface water and ecological receptors.

There were 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 presence of intensive agricultural practices in the south-east suggests that diffuse agricultural sources are the cause of the elevated nitrate concentrations; 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 wastes, such as septic tank effluent or farmyard manure. 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.

The WFD establishes a framework to protect all waters through integrated management and assessment of the interactions between different water types. To meet the objectives of the WFD, an improved understanding of the interactions between groundwater and surface water receptors is required. Gaining this understanding is a fundamental need if further deterioration in water quality is to be prevented and the sustainability of water resources is to be achieved.

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