Groundwater

Groundwater is a hugely valuable asset, particularly for rural communities, where it provides most of the private drinking water. More than 80% of groundwater is in good condition.

Summary

Scotland's groundwater is a hugely valuable hidden asset. It underpins communities in rural Scotland, providing 75% of private drinking water supplies. It also supplies 70% of the water bottled by the distilling industry.

More than 80% of Scotland's groundwater is in good condition; although there are particular regions with widespread problems, for example in the Central Belt. There are also a large number of local problems affecting private water supplies.

Agriculture and the legacy of industrial activity are the main causes of regional-scale groundwater problems, whereas inadequate construction of private water supplies and inappropriate management of wastes cause the localised problems.

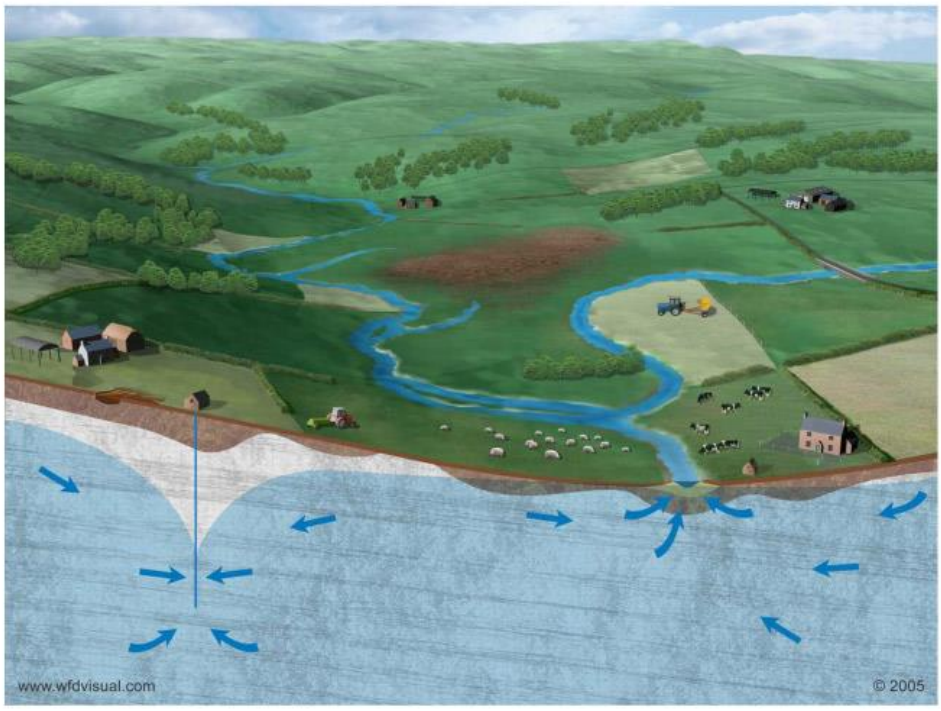
Introduction

Benefits and functions of groundwater

Groundwater usually starts life as rainfall. Some rain is taken up by plants, some runs over the land surface and some soaks through the soil to top up the 'water table'. Below this level, all the spaces in the soil or rock are completely filled with water – groundwater. In Scotland, the water table is usually within 5 m of the ground surface.

Groundwater moves slowly underground towards lower areas until it meets the ground surface again and seeps out as springs, or in boreholes, rivers or directly into the sea.

Figure 1: The groundwater cycle; providing drinking water and supporting flows in rivers



Source: www.wfdvisual.com/Search.aspx

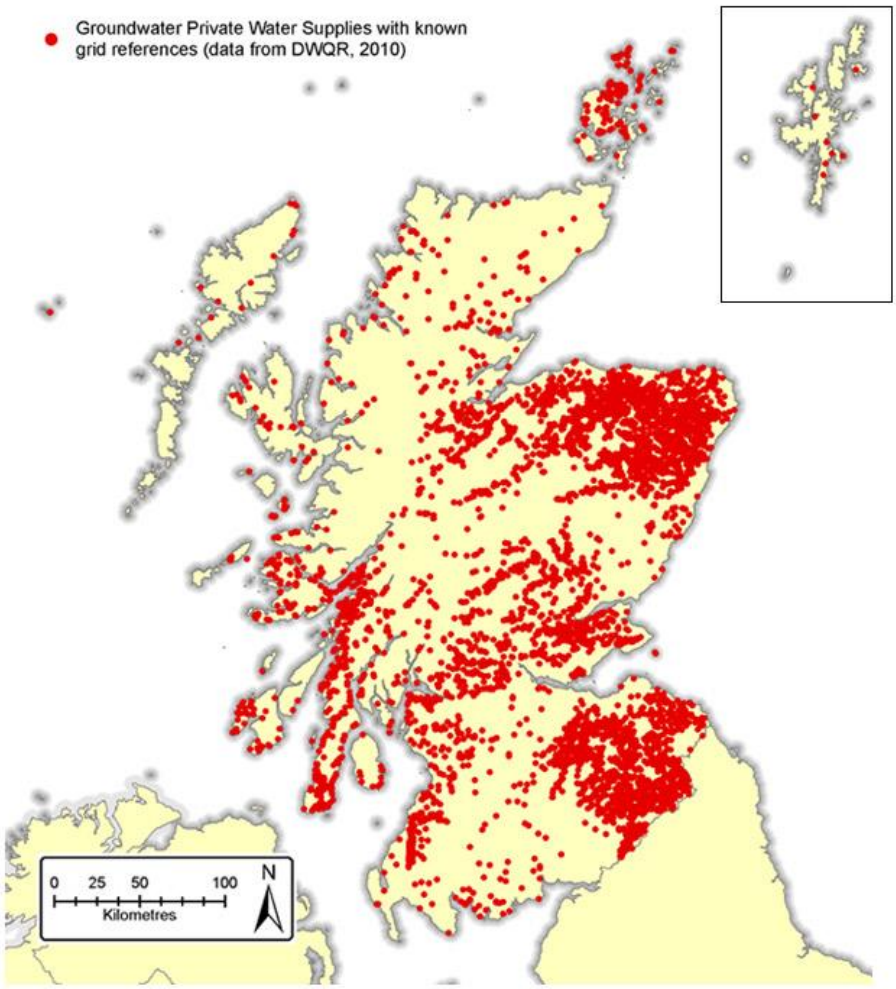
Groundwater is a hugely valuable water resource for Scotland. It provides:

- 73% of Scotland's private water supplies; supplying at least 80,000 people mainly in rural areas (Figure 2);
- 5% of Scotland's public water supply, drawn from 96 boreholes and springs. In total, groundwater provides the water supply for at least a third of a million Scots;
- approximately 70% of the water bottled by the distilling industry process. The economic benefits of the Scotch whisky industry are significant, contributing £3.9 billion a year in Gross Value Added to the Scottish economy, after supply chain spending is taken into account. Scotch whisky is Scotland's leading export after oil and gas;
- all of the water used by the bottled water industry – abstraction of up to 14.7 million litres of groundwater per day is licensed.

Groundwater is extracted for a variety of other industries including fish farming, mining, agricultural irrigation and brewing.

In total, SEPA licenses the abstraction of over 750 million litres of groundwater per day, which would be enough water to supply the domestic needs of the populations of the greater urban areas of Glasgow, Edinburgh and Birmingham combined.

Figure 2: Location of private drinking water supplies provided by groundwater.



Source: Drinking Water Quality Regulator

As well as being used directly by people, groundwater also plays an important role in supporting surface ecosystems.

- on average, it supplies around one-third of the annual flow in all Scottish river bodies. This proportion increases to over 60% in some eastern rivers;
- it supports almost two-thirds of all statutory designated wetland sites in Scotland, providing the volume of water and nutrients essential for the health of these sites.

Groundwater underlies the whole of Scotland but its depth, quality, quantity and value to society vary significantly across the country, depending on many factors, especially the geology. A geological formation capable of providing a groundwater resource is called an 'aquifer'.

The widespread distribution of groundwater drinking water supplies across Scotland (Figure 2) means that all parts of mainland Scotland, and almost all inhabited islands, have been identified as aquifers of some kind by the British Geological Survey. The least productive aquifers are in the north-west. They are capable of providing abstractions for widely dispersed homes or small settlements of at most perhaps 50 people and there are only a few highly productive aquifers in Scotland capable of providing drinking water for tens of thousands of people (e.g. around Turriff, Forres and Dumfries).

Aquifers have been subdivided by SEPA into subunits for the purposes of managing the groundwater resource. These subunits are called groundwater bodies.

Description of groundwater

The state of groundwater is assessed by different methods depending on its intended use.

Groundwater used for drinking water is monitored at the tap; the results are compared against the EU Drinking Water Directive, as set out in the Private Water Supply Regulations.

The assessment of the overall groundwater resource and the effects on ecosystems which rely on groundwater is part of the Water Framework Directive (WFD) classification process. More details on the classification scheme can be found in the 2008 State of the Water Environment report and the classification scheme is explained further in the Policy statement on Water Environment and Water Services (Scotland) Act 2003.

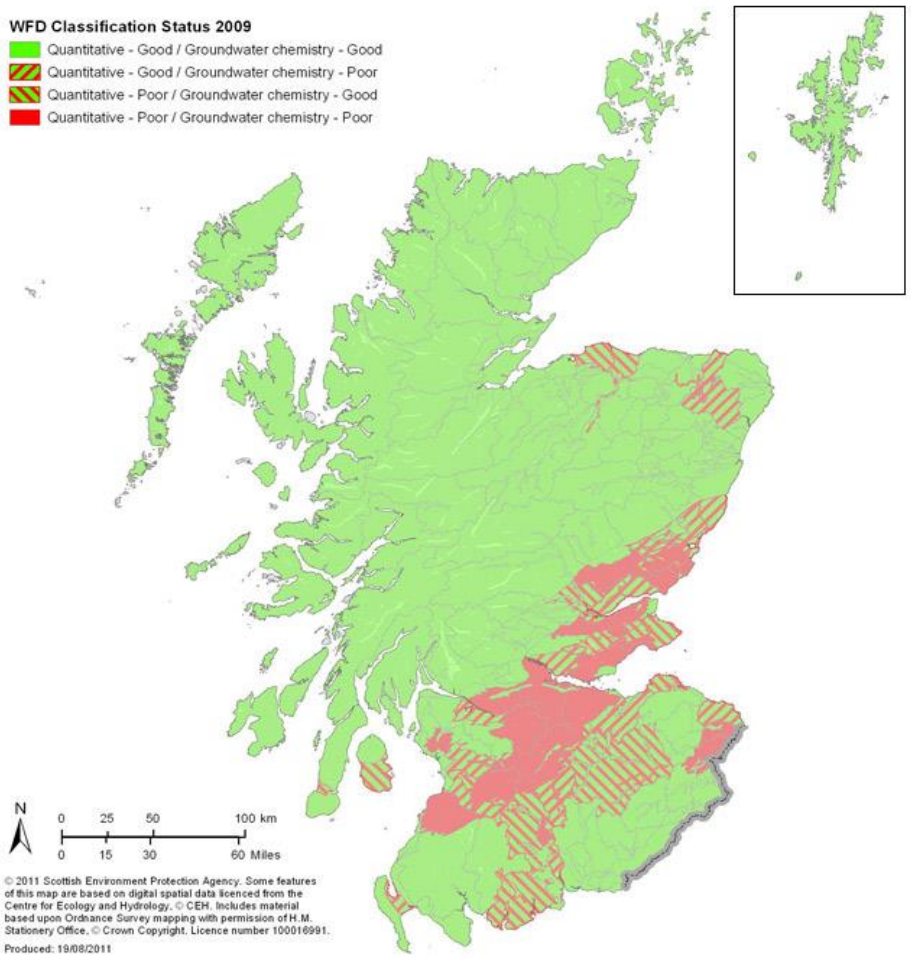
Groundwater monitoring is extremely expensive; long-term sampling infrastructure often costs several thousands, or even tens of thousands of pounds for each borehole. Consequently, groundwater assessments combine monitoring information with data from monitoring of rivers, lochs and wetlands, and modelling information.

The full classification results for each individual water body can be found by following the links at the River Basin Planning webpage.

Condition

According to the 2009 River Basin Management Plan, 13% of the total area of Scotland's groundwater is impacted by potential pollutants such as nitrates or toxic metals. The total area affected is small, and occurs in clusters; the largest clusters occur in the Central Belt, north-east and south-east Scotland. Particular problems occur where a cluster coincides with a high reliance on groundwater for supplying drinking water, for example, in rural Aberdeenshire.

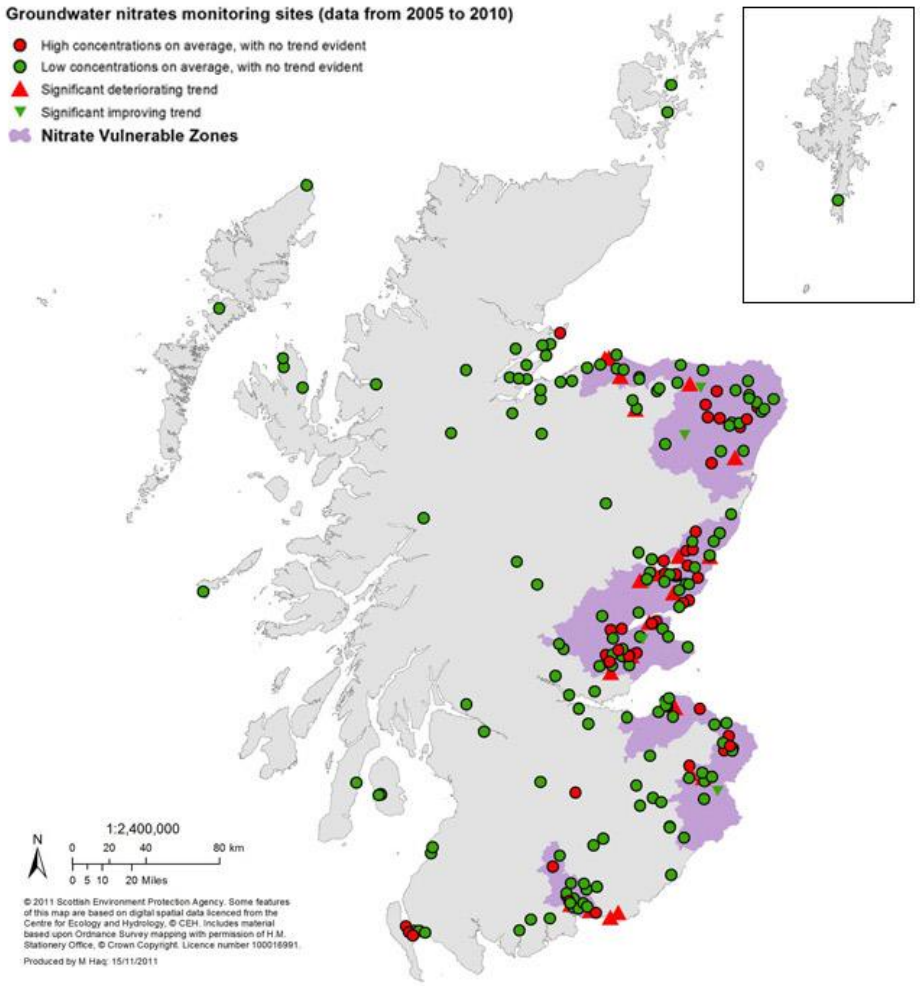
Figure 3: Groundwater status for chemical status and groundwater levels



As well as these clusters, there are also very localised incidences of contamination of individual drinking water supplies. These occur across Scotland, and are usually due to poor construction of groundwater abstractions or poor management of nearby sources of contamination. The most common problem is microbial pollution (from bacteria) although incidences of ammonium and pesticide pollution also occur. Some 23% of all private groundwater well supplies sampled in 2010 were impacted by *Escherichia coli.* These problems are distributed across supplies in all Scotland's local authority areas.

Over-abstraction of the groundwater resource also occurs. According to the 2009 River Basin Management Plan, some 10% of the total area of Scotland is over-abstracted. The total area is small but impacts occur in localised clusters, with the largest clusters occurring in the Central Belt, Strathmore in Fife, East Lothian, the Moray Firth and Dumfries.

Figure 4: Nitrate pressure from agriculture; nitrate vulnerable zones and nitrate trends



Widespread groundwater monitoring networks were established in Scotland in the late 1990s and early 2000s. There are insufficient long-term records to establish clear trends on all pressures. The longest-term evidence available is for nitrate and water levels.

Trends in groundwater nitrate concentrations across Scotland are shown in Table 1. This table provides the results of a statistical analysis of 153 groundwater monitoring sites for which nitrate data are available for at least 6 years. Six years is the minimum period over which a trend can be definitively identified in groundwater.

Table 1: Statistical analysis of groundwater nitrate concentrations at monitoring points across Scotland

	Statistical analysis using 6 years of data 2005–2010	**Statistical analysis using 3 years of data 2008–2010**
Percentage of sites showing an improving trend	31	25
Percentage of sites showing a statistically deteriorating trend	27	13
Percentage of sites showing no evidence of a trend	42	61

Table 1 shows that most monitoring points have had stable nitrate concentrations over the 6-year period between 2005 and 2010, although over a quarter of sites are deteriorating.

More recent 3-year trend assessments although not statistically robust, are provided in Table 1 for comparison. This comparison shows that fewer sites are deteriorating, suggesting that the situation will improve in future years.

For water levels, there are very few sites with more than 5 years of data, so it is not possible to show clear evidence of statistically significant trends across Scotland.

Pressures affecting groundwater

The main pressures on groundwater are outlined in the 2009 River Basin Management Plan (RBMP). These are summarised in Table 2 and described in more detail in the following text.

Table 2: Combined summary of chemical and abstraction impacts across Scotland; data from 2009

Activity	Pressure	Area of groundwater bodies at poor status (%)
Agriculture	Inputs of nitrates	6
	Irrigation abstraction	4
Water supply	Public supply abstraction	2
	Other abstraction, including food and drink	2
Mining, waste and legacy industrial activity	Dewatering abstractions	3
	Inputs of hazardous substances and electrical conductivity	9
Other	Microbial pathogens (bacteria), pesticides, ammonia	Small, localised impacts

Pollution: Inputs of nitrate

Nitrate is an essential plant nutrient and is added to the soil to optimise plant growth. At low concentrations in groundwater it is harmless; however, at high concentrations it can become harmful to human and animal health as well as the ecological health of the water environment. Groundwater drinking water supplies can be affected. Contaminated groundwater, via discharges to river systems, can also lead to problems with nutrient enrichment and excessive algal growth in estuaries.

A recent detailed monitoring study in the Ythan catchment of Aberdeenshire has shown that over 90% of the total nitrate problem in this catchment is due to agriculture. Most of the remainder comes from deposition from the air, and less than 1% comes from direct discharges such as landfills, septic soakaways and cemeteries.

A map showing the impact of nitrates is shown in the description section.

Pollution: Inputs from legacy industrial activity

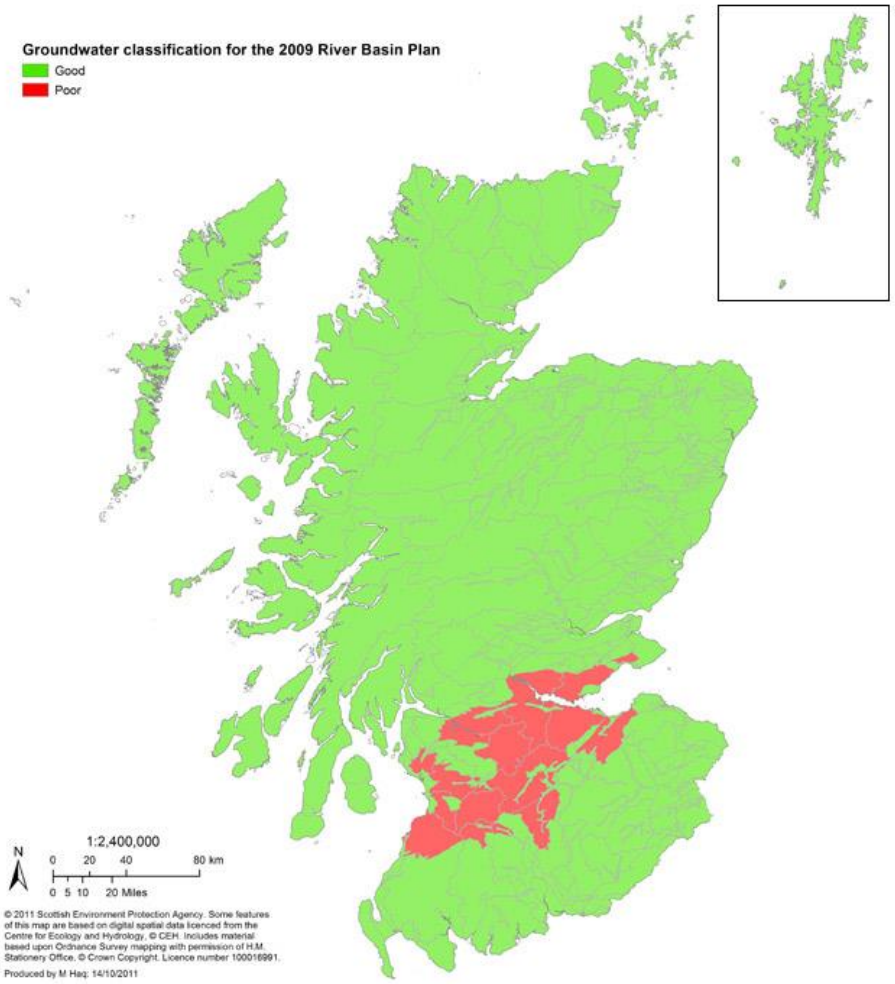
Historic coal mining is the main pressure within this category; in fact this is the most extensive single pressure on Scotland's groundwaters, because of the very extensive areas of historic coal mines. Groundwaters are contaminated with toxic metals and minerals when they flood abandoned mine workings; some of these pollutants are classified as “hazardous”. If they flood sufficiently to be discharged into surface waters, they can cause severe ecological damage.

Land contamination by historic activities has also led to elevated levels of toxic substances in groundwater. Currently, the largest area of groundwater known to have been impacted by land contamination is due to the historic chromium plating industry in Glasgow. The contaminated groundwater is, in turn, directly affecting the River Clyde as it discharges into the river, and indirectly affecting several other surface waters. There are a number of other localised pollution hotspots, but it is unknown how many groundwater bodies are impacted by their cumulative effects.

Landfills can cause locally significant releases of ammonia or hazardous substances if not designed and maintained in accordance with best practice. As with land contamination, it is currently unknown whether the cumulative impact of landfilling in certain areas has been sufficient to impact on the status of whole groundwater bodies.

Pesticide impacts have also been identified over a small proportion of the total groundwater body area. For example, localised and sporadic local impacts have been identified in the Ythan catchment. Inappropriate handling or storage of agricultural pesticides is thought to be the most likely cause of the problem in this catchment. The pattern is likely to be repeated in other catchments dominated by intensive agricultural practices.

Figure 5: Poor status groundwater bodies due to legacy industrial activity



Pollution by microbial pathogens

Microbial pathogens (bacteria which cause disease) can have a significant impact on human health if found in drinking waters.

Information for the 2010 report by the Drinking Water Quality Regulator shows the following distribution of *E. coli* failures in private drinking water supplies:

- surface water supply – 23% of samples failed the standard;
- groundwater spring supply – 18% of samples failed;
- groundwater well supply – 19% of samples failed;
- groundwater borehole supply – 6% of samples failed.

Microbial contamination tends to occur near the point of abstraction usually due to a combination of local mishandling of wastes and inadequate siting and construction of private water supplies.

Clearly, these problems could be improved by better disinfection at the point of abstraction, but the cause of the microbial problem should also be addressed.

Generally, the deeper the source, the fewer problems encountered. Boreholes tend to be drilled deeper than wells and springs, with surface water being the shallowest source.

Examples of potential sources of the problem include inadequately constructed septic soakaways and inadequate storage of farmyard slurries. For example, it may be that a rural household has a septic tank that is not properly constructed and may be leaking into the household's well.

Over-abstraction

Unsustainable abstraction of groundwater causes water table levels to fall, which, in turn, can cause river flows to drop, as well as impact on neighbouring abstractions.

Approximately 4% of Scotland's groundwater is affected by over-abstraction for agricultural irrigation, with a further 4% being damaged by abstraction for drinking water and water to supply industry.

More information on the evaluation of abstraction and chemical point source pressures is included here.

Consequences of a change in groundwater

Although groundwater is eventually replenished by rainfall, this generally happens over a long timescale; consequently, once a groundwater is damaged it takes a long time to recover. The main consequences of groundwater damage are:

- potential impacts on human health. This is a combination of localised impacts from microbial contamination and hazardous substances, along with more widespread impacts from nitrate pollution in the east, north-east and south of the country;
- impacts of abstraction on river flows, predominantly as a result of irrigation abstraction in the east of the country;
- impacts on ecology. This includes the impact of nitrate pollution from agriculture on estuaries in the east of the country and the impact of legacy industrial contamination on river quality in the Central Belt.

Response by Society

Groundwater is a very important resource. If damaged, restoration is difficult and can take many years to achieve, therefore legislation has a particular emphasis focussing on restricting pollutants, particularly hazardous substances, at the point of release. It also emphasises identifying and addressing risks before they become serious impacts. More information on groundwater regulation can be found in SEPA guidance.

Existing measures are summarised in Table 3.

New environmental problems and priorities for future measures

For most sites monitoring for groundwater started less than ten years ago. Therefore, the key challenge is to improve our understanding of pressures and the impacts these have on groundwater. The main areas for further work are to understand the extent of hazardous substance problems in groundwater bodies, the cause and extent of microbial problems in groundwater private drinking water supplies, and the nature of impacts on groundwater-dependent wetlands. It may also be necessary to review the standards used when drilling water wells, to ensure drinking water supplies aren't affected by local contamination.

Table 3: Summary of responses to groundwater pressures

Groundwater pressure	Response
Nitrates (agriculture)	**Reduced nutrient inputs to the water environment** - Note that the Nitrates Action Programme rules were tightened with effect from 2009. This may explain a recent reduction in the number of monitoring sites with deteriorating nitrate concentrations (refer to Table 1). **Legislative** - Water Environment (Controlled Activities) (Scotland) Regulations 2011 - Control of Pollution (Silage, Slurry, and Agricultural Fuel Oil) (Scotland) Regulations 2003 - Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations (2008) **Economic** - Scotland Rural Development Programme - Cross-Compliance and Good Agricultural and Environmental Condition (GAEC) (Cross-Compliance) (Scotland) Regulations 2004 **Education and advice initiatives** - National awareness raising campaign - Work with farmers in priority catchments - Trial catchment projects - Demonstration farms

Nitrates and microbial pathogens (sewage discharges to soakaways)	**Reduced pollutant inputs to the water environment** **i) Control at source** Ensure pollutant is not included in affected product, or conditions of use made clear to consumer **Legislative** Marketing and use legislation **ii) 1st time sewerage**
Nitrates and ammonia (cemeteries)	**Control of design and location of sites** **Legislative** - Town and Country Planning (Scotland) Act 1997
Hazardous substances (agriculture)	**Reduced pesticide inputs to the water environment** **Legislative** - Water Environment (Controlled Activities) (Scotland) Regulations 2011 - Legislation on the sale and use of pesticides, including: Food and Environment Protection Act 1985 - Plant Protection Products (Scotland) Regulations 2005 - Control of Pesticides Regulations 1986 **Economic** - Scotland Rural Development Programme - Cross-Compliance and Good Agricultural and Environmental Condition (GAEC) **Education and advice initiatives** - Development and promotion of guidance - Delivery of on-site advice - Voluntary Initiative for Pesticides 42 - Sheep Dip Pollution Reduction Programme 43

Hazardous substances (abandoned mines)	**Reduce/treat discharges into surface waters of polluted minewater from abandoned mines** **Legislative** - Water Environment (Controlled Activities)(Scotland) Regulations 2011 **Economic** - Public funding of Coal Authority remediation schemes
Hazardous substances (land contamination)	**Understand cost benefit and remediate accordingly** **Legislative** - Town and Country Planning (Scotland) Act 1997 - Part IIA of the Environmental Protection Act 1990 **Economic** - Publically funded investment
Hazardous substances, chloride and ammonia (waste disposal at landfill sites)	**Control the location, design and management of landfills** **Legislative** - Town and Country Planning (Scotland) Act 1997 - Pollution Prevention and Control (Scotland) Regulations 2000 - The Waste Management Licensing (Scotland) Regulations 2011
Hazardous substances (deep disposal/new energy technologies)	For example, radioactive disposal, shale gas or coal bed methane extraction, geothermal energy or underground coal gasification **Control of inputs of pollutants to the water environment and abstractions from the water environment** **Legislative** - Water Environment (Controlled Activities) (Scotland) Regulations 2011 - Pollution Prevention and Control (Scotland) Regulations 2000

Abstraction	**1. Reduce demand** **Legislative** - Water Environment (Controlled Activities) (Scotland) Regulations 2011 **Economic** - Publically funded investment programme for Scottish Water (Quality and Standards) - Scotland Rural Development Programme funding for storage ponds **2. Improve water use efficiency to enable reduced abstraction** Scottish Water charging scheme for business customers **Education and advice** - Scottish Water Customer Support - Guidance and publicity on industrial best practice - Vision in Business for the Environment of Scotland (VIBES) competition on industrial best practice - Information for customers on how to use water efficiently particularly in at risk areas **3. Increase supply capacity** For example, integrate and optimise relative use of different sources; increase capacity of existing source (e.g. install storage for peak demands, increase reservoir capacity); develop additional sources **Legislative** - Water Environment (Controlled Activities) (Scotland) Regulations 2011 **Economic** - Publically funded investment programme for Scottish Water (Quality and Standards)