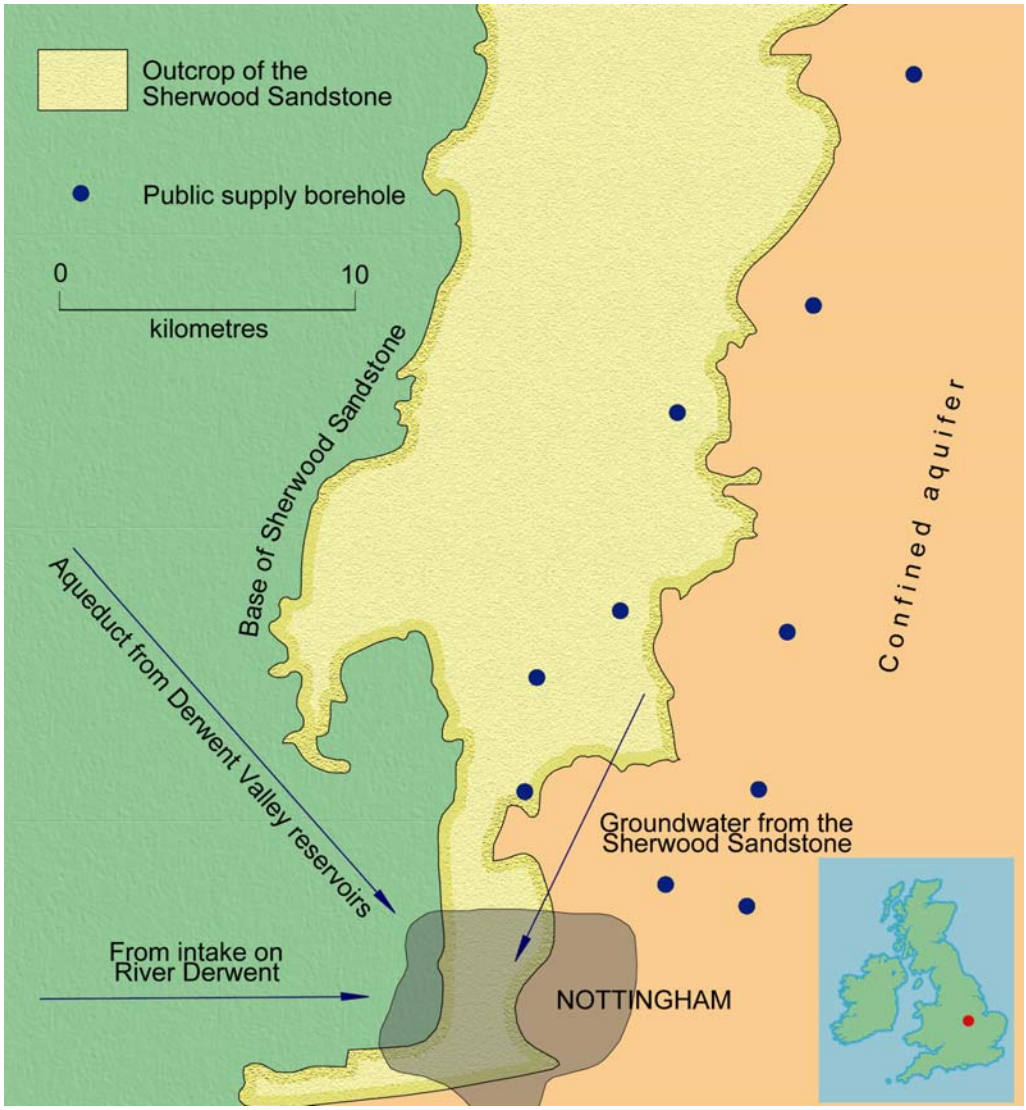
The Nitrate Problem

Nitrogen is an essential plant nutrient: some plants fix atmospheric nitrogen but modern farming practice involves the addition of nitrogen in the form of manure, sewage sludge and chemical fertilisers. The accumulation of soluble forms of nitrogen, particularly nitrate, in water can be detrimental since high concentrations in river water encourage eutrophication, and concentrations in drinking water must be limited for health reasons.

During and after the Second World War, as agriculture was gradually modernised, farming practices became much more intensive. Two changes had consequences for water quality. Firstly, large areas of virgin grassland were ploughed and this led to the oxidation of nitrogen in organic matter in the soil and, secondly, the application of artificial nitrogenous fertilisers to crops began to increase significantly in the 1950s. These changes increased the amount of nitrate leached from the soil by infiltrating rain and eventually a gradual but marked increase in the concentration in groundwater in the affected areas became evident in the early 1970s. Pollution from such widespread sources is referred to as diffuse contamination.

The rate of movement of water, and hence of nitrate, from the soil zone to the saturated zone is influenced by the depth of the water table, that is the thickness of the unsaturated zone, and the properties and nature of the aquifer. Water can pass quickly through fractured rocks, at rates of some tens of metres per days, but much more slowly through the matrix of chalk and sandstone. The velocity through the matrix of the Chalk is only about 1 m / year. Where the unsaturated zone



Sources of water supply for Nottingham and the surrounding region.

is thick there can be a delay of many years before an increase in the amount of nitrate leached from the soil affects groundwater quality.

The nitrate concentration in groundwater is influenced by rainfall. Where the amounts of rainfall are low, the concentration tends to be high because the diluting effect is reduced. Hence the worst affected areas are the drier eastern and central parts of England where the Chalk, the Permo-Triassic sandstones and the Lincolnshire Limestone are found at the surface.

Nitrate contamination is a long-term problem and remedial action is necessary. The cost of chemical treatment to remove it from groundwater is significant and disposal of water products from the process can also be difficult. An alternative course is to reduce the contamination at the source – the amount leaching from the soils, which mainly occurs in the autumn and winter when the soil is fully saturated.

The scale of the problem can be reduced by better land management including:

- reducing the use of artificial fertilisers,
- reducing the extent of ploughing in the autumn,
- sowing autumn crops early,
- avoiding bare ground in the winter by sowing cover crops,
- delaying the ploughing-in of crop residues,
- carefully managing the disposal of farm wastes.

Nevertheless, despite more careful management, where the unsaturated zone is thick, it will be many years before beneficial effects from changes in farming practices are seen in the quality of groundwater.

Limiting the effect of nitrate

High concentration of nitrate in drinking water can be detrimental to human health. Infants under one year old are particularly at risk from excessive amounts as it causes methaemoglobinaemia, commonly called 'blue baby syndrome'. A further concern is that nitrate can be converted, by bacteria in the digestive tract, into nitrosamines which are potentially carcinogenic. However, whether low levels of nitrate are harmful is often contested.

In 1980, the Drinking Water Directive of the European Community set a maximum limit for nitrate in water of 50 milligrams per litre (mg/l). On this basis many public supply sources were providing groundwater with concentrations exceeding or close to the limit. In 1989 about 1% of the population of the UK were receiving water which failed to comply with the Directive and water from almost 200 public supply sources exceeded 50 mg/l at some time. Some boreholes were taken out of use, water from others was blended with low nitrate sources, and in yet others the water was treated to remove nitrate.

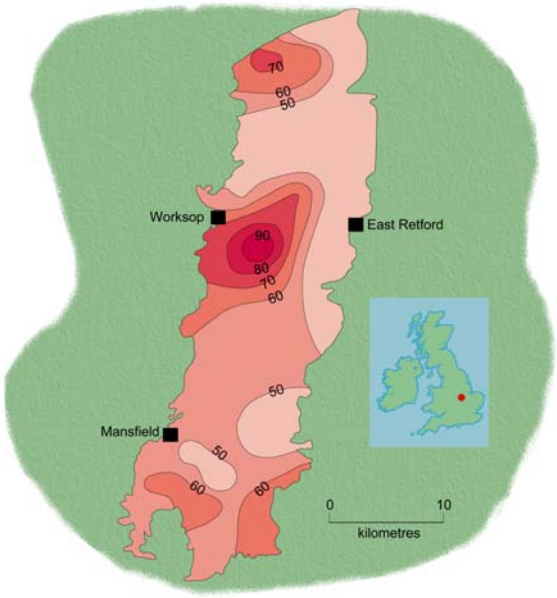
To guarantee better farming practices, firm direction in the form of legislation was necessary. In 1991, the European Community issued a Nitrate Directive which requires states to identify waters that were or could be affected by nitrogen pollution from agricultural sources, and to designate as 'nitrate vulnerable zones' (NVZs) the land from which pollutants are derived.

Currently 55% of England and Wales and 14% of Scotland have been designated as NVZs. It is hoped that measures adopted in these zones will significantly reduce the amount of nitrate leaching from the soil. The basis for these measures was a series of large-scale experiments that began in 1990. Ten groundwater catchments, subsequently increased to 32, were selected as 'Nitrate Sensitive Areas'. Farmers in these areas were offered payments in return for complying with rules for the use of fertiliser and manure, and the maintenance of a green ground cover in winter and, in some areas, conversion of arable land to grassland. Nitrate leaching from some of these nitrate-sensitive areas were reduced although it will be longer before the benefits to water supplies are realised.

Managing groundwater resources in south Nottinghamshire

Nottingham lies at the southern end of an extensive outcrop of the Triassic Sherwood Sandstone, which represents one of the largest groundwater reservoirs in the UK. Since the nineteenth century, the city has taken advantage of this to obtain water supplies from deep wells and boreholes in the sandstone. The aquifer is now fully developed and the long-term objective is to reduce abstraction to a sustainable level which will allow continuous use of the aquifer without damaging surface water features. This has already been partially achieved by reducing the quantities of water that can be abstracted under license. At present the sandstone provides about 50% of the supply for the city and surrounding region.

The balance of the water requirements for the city is taken directly, by aqueduct, from surface reservoirs in the Derwent Valley, and from the River Derwent itself near Derby. The flow of the river is regulated by releasing water for this



Distribution of nitrate in groundwater in the outcrop of the Triassic Sherwood Sandstone of Nottinghamshire in 1993. The map shows where values exceeded 50 mg/l. This is the maximum admissible concentration in drinking water as stipulated by the European Union.

purpose from the Carsington Reservoir, in the Derwent Valley some 20 km north of Derby.

The concentration of nitrate in groundwater in the outcrop area of the Sherwood Sandstone has been steadily rising since the late 1960s. It now exceeds 50 mg/l over significant areas, exceeding the limit for drinking water stipulated by the European Union. This has been overcome by blending high-nitrate water from the outcrop with water from the confined aquifer, east of the outcrop, which contains water with a low nitrate concentration. New boreholes have been drilled in the confined zone and also in afforested areas on the outcrop of the sandstone, which also yield water with low concentrations of nitrate. Some areas on the outcrop of the sandstone, within catchments of public supply boreholes, were designated 'Nitrate Sensitive Areas'. Within these areas farmers received payments for changing farming practices, including reducing the application of fertilisers and manure, so as to reduce the amount of nitrate that can be leached from the soil.

Pesticides Gain Access to Groundwater

Pesticide is a general term applied to herbicides, fungicides and insecticides that are used to kill pests and weeds. They are widely used for weed control in agriculture, on roads and railways, and to control pests in industry.

Synthetic organic pesticides where introduced during the Second World War and their use expanded rapidly in the 1950s and 1960s. By providing effective control of pests they have been a great benefit to agriculture, and in conjunction with the use of fertilisers, have increased crop yields considerably. However, by the early 1960s, undesirable effects on the environment, were apparent. Rachael Carson drew attention to the risk to groundwater as long ago as 1962 in her classic book *Silent Spring*. But the measurement of pesticides at low concentration in water is complex and expensive, and the routine examination of groundwater for them is a recent event, as is a more widely perceived appreciation of their risk to groundwater quality.

The fate and behaviour of pesticides is controlled by the extent of their uptake by crops, and their susceptibility to leaching and degradation. Although their behaviour in the soil is relatively well known, in aquifers it is more obscure. Those that are soluble will clearly move through the unsaturated zone but their progress may be delayed by adsorption and they may degrade biologically, although the microbial population, and nutrients in the form of organic matter, are much reduced below the soil zone. Rapid flow through fractured aquifers poses a particular risk to groundwater quality.

Investigation of the distribution of pesticides in groundwater is in its early stages and the environment agencies are currently improving their monitoring programmes. However, it is clear that pesticides do occur in groundwater, albeit in small concentrations, generally below the EC maximum admissible concentration (MAC) of 0.1 microgram per litre. As their movement through the unsaturated zone is likely to be slow and measured in decades in many aquifers, studies of their distribution in this zone seems to be an essential step in defining the extent of the eventual problem in the saturated zone.

The water industry has introduced treatment processes to remove pesticides although the cost of treatment is high. Steps are also taken to encourage their careful use, storage and disposal, particularly near public supply boreholes. Some water companies have secured agreements with regular users of pesticides to restrict their use in areas where groundwater is susceptible to contamination.