

Human influence on environmental systems is so profound that it can be difficult to distinguish natural variations from man-made impacts. **Andrew McKenzie** describes how to work out the quantity and quality of groundwater we may expect our planet to provide.

Groundwater — so what's normal?

Groundwater is perhaps unique among geological resources in that it is renewable, and a resource that can be actively managed. Hydrogeologists seek to integrate an understanding of geology and of water's behaviour in the environment to understand how natural groundwater systems behave.



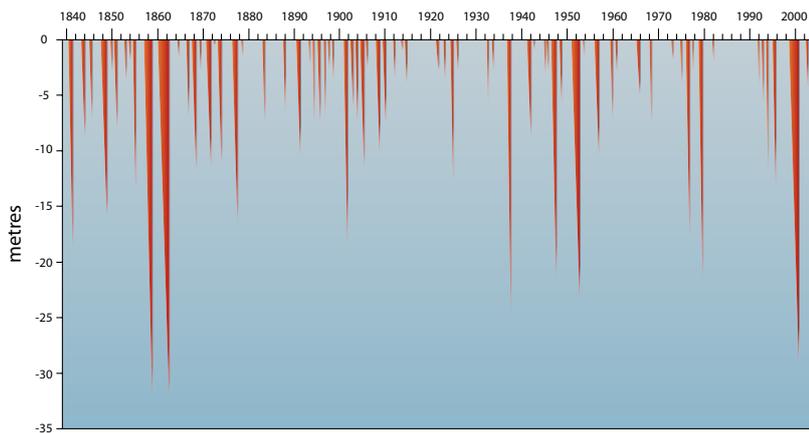
Step well: a 'baoli' constructed in the tenth century.

One of the great challenges of hydrogeology is that few aquifers, at least in the developed world, are undisturbed by human activities, whether through abstraction, changes in land use, or pollution. In 1827, eight years before the establishment of the BGS, William Smith, the author of the world's first geological map wrote about 'modifying an aquifer to retain water for summer use', and ever since groundwater has been aggressively exploited. Knowledge of the natural 'baseline' behaviour of groundwater is an essential foundation that allows us to decide how to manage an aquifer. BGS scientists work in a long tradition of determining these baseline conditions.

An example of this is the derivation of information on drought frequency (or flood frequency) from the observations of water levels in wells.

The level of water in an aquifer fluctuates in response to inputs into the aquifer from rainfall, and outputs, either by natural flows to springs and rivers, or through pumping. When groundwater levels are lowered by pumping, this can reduce flow in rivers, with consequent impacts on the environment.

Our scientists measure the water level in wells and boreholes to build up a picture of fluctuations over time. Some wells in undisturbed aquifers have been monitored continuously for more than a hundred years, in one case since 1835,



Drought frequency, cumulative departures from expected monthly mean levels, in metres, for the Chilgrove well.

providing a record that can potentially reveal long-term environmental change. In practice, geological limits on the fluctuation of water levels mean that long-term rise or decline in levels is only seen where aquifers have been heavily pumped, but changes in the frequency of extreme events, whether drought or flood, can be seen in undisturbed aquifers.

Data from Chilgrove, a Chalk well in southern England, have been analysed, comparing monthly water levels with long-term mean averages to create a drought index. Over a period of 160 years, droughts with cumulative level deficits of more than 10 metres, have occurred about once every 7 years; more serious droughts with a deficit over 20 metres once every 23 years. Rather than showing clear periodicity, the droughts are scattered in time, with little pattern and occasional clustering. Research continues into the climatic factors that control both droughts and floods, but the long-term data show the risks associated

with assuming that records gathered over short periods are representative of either the full range of aquifer behaviour, or even of typical behaviour.

The danger of making assumptions on limited observations is illustrated by an example from New Delhi, India. A traditional form of well in the Indian subcontinent is a ‘baoli’ or step well, dug large enough for the construction of steps to the water table for easy access. In the 1970s, water levels in New Delhi were near the surface and many step wells were full. Water levels have dropped since then and many step wells are now dry. A common perception has been that the levels in the 1970s were normal, and the subsequent falls have been due to over-abstraction. There certainly has been over-abstraction, but the wells would originally have been dug down to the water table; the technology to excavate tens of metres below the water table did not exist when the step wells were constructed. Even with deepening during

droughts, it is almost certain that the 1970s water tables were abnormal, the result of leaking mains, sewers, and irrigation return. The natural level of Delhi’s aquifers probably lies close to the well’s lower galleries. We are now helping to upgrade the monitoring of groundwater across India.

Groundwater in its natural state is normally a clean and safe source of water, with natural filtration processes protecting against bacteriological contamination. Groundwater can, however, be polluted by agricultural or industrial chemicals, and considerable effort is expended in controlling pollution, and in cleaning up and remediating aquifers after pollution has occurred.

Water samples are analysed to measure both the natural constituents and the level of any pollutants. If these pollutants are man-made chemicals, pollution is easy to recognise, but if the pollutants occur in nature it can be hard to pinpoint their source. Reactions between groundwater and minerals can lead to natural concentrations of chemicals that are above the levels considered safe — perhaps the most serious example of this being arsenic concentrations in aquifers in the Gangetic delta.

Systematic surveying of natural groundwater quality in the UK has established a baseline for groundwater quality, which can be used both to detect pollution against the natural background and to allow regulators to set targets for remediation.

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“ For the means of altering or improving some of these natural operations, so as to render the irregular supply of water which falls upon the earth more convenient to the general purposes of man, we must resort to geology; — to find what stratum is fitting for the object, and what site in the range thereof; what the rock lies upon; what stratum or diluvium covers it, and the dip, rises, and troughs or undulations in the strata. ”

William Smith 1827

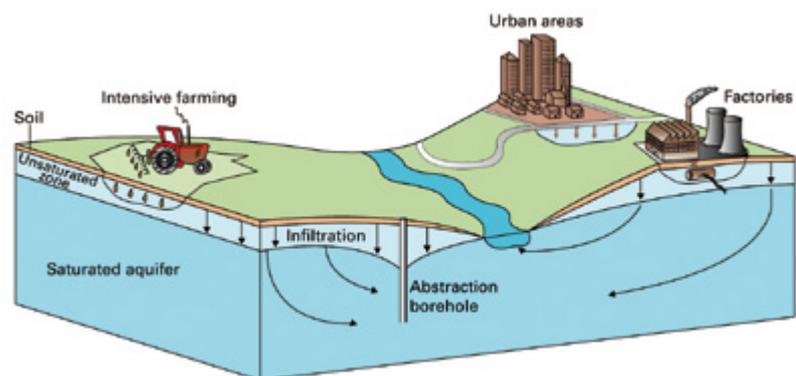


Illustration of the variety of natural and anthropogenic inputs and a range of flow pathways that give rise to large variations in water chemistry.